SUSE

openSUSE Leap 15.5

Virtualization Guide

Virtualization Guide

openSUSE Leap 15.5

This guide describes virtualization technology in general. It introduces libvirt—the unified interface to virtualization—and provides detailed information on specific hypervisors.

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Preface

1 Available documentation

Online documentation

Our documentation is available online at https://doc.opensuse.org ↗. Browse or download the documentation in various formats.

> **Note: Latest updates**
>
> The latest updates are usually available in the English-language version of this documentation.

In your system

For offline use, the release notes are also available under `/usr/share/doc/release-notes` on your system. The documentation for individual packages is available at `/usr/share/doc/packages`.

Many commands are also described in their *manual pages*. To view them, run **`man`**, followed by a specific command name. If the **`man`** command is not installed on your system, install it with **`sudo zypper install man`**.

2 Improving the documentation

Your feedback and contributions to this documentation are welcome. The following channels for giving feedback are available:

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Report issues with the documentation at https://bugzilla.opensuse.org/ ↗.

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For more information about the documentation environment used for this documentation, see the repository's README at https://github.com/SUSE/doc-sle.

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Help

If you need further help on openSUSE Leap, see https://en.opensuse.org/Portal:Support.

3 Documentation conventions

The following notices and typographic conventions are used in this document:

- `/etc/passwd`: Directory names and file names
- *`PLACEHOLDER`*: Replace *`PLACEHOLDER`* with the actual value
- `PATH`: An environment variable
- **`ls`**, `--help`: Commands, options, and parameters
- `user`: The name of a user or group
- `package_name`: The name of a software package
- Alt , Alt – F1 : A key to press or a key combination. Keys are shown in uppercase as on a keyboard.

- *File*, *File › Save As*: menu items, buttons
- *Chapter 1, “Example chapter”*: A cross-reference to another chapter in this guide.
- Commands that must be run with `root` privileges. Often you can also prefix these commands with the **`sudo`** command to run them as non-privileged user.

  ```
  # command
  > sudo command
  ```

- Commands that can be run by non-privileged users.

  ```
  > command
  ```

- Notices

Warning: Warning notice

Vital information you must be aware of before proceeding. Warns you about security issues, potential loss of data, damage to hardware, or physical hazards.

Important: Important notice

Important information you should be aware of before proceeding.

Note: Note notice

Additional information, for example about differences in software versions.

Tip: Tip notice

Helpful information, like a guideline or a piece of practical advice.

- Compact Notices

Additional information, for example about differences in software versions.

Helpful information, like a guideline or a piece of practical advice.

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1 Virtualization technology

Virtualization is a technology that provides a way for a machine (Host) to run another operating system (guest virtual machines) on top of the host operating system.

1.1 Overview

openSUSE Leap includes the latest open source virtualization technologies, Xen and KVM. With these hypervisors, openSUSE Leap can be used to provision, de-provision, install, monitor and manage multiple virtual machines (VM Guests) on a single physical system (for more information see *Hypervisor*). openSUSE Leap can create virtual machines running both modified, highly tuned, paravirtualized operating systems and fully virtualized unmodified operating systems.

The primary component of the operating system that enables virtualization is a hypervisor (or virtual machine manager), which is a layer of software that runs directly on server hardware. It controls platform resources, sharing them among multiple VM Guests and their operating systems by presenting virtualized hardware interfaces to each VM Guest.

openSUSE is a Linux server operating system that offers two types of hypervisors: Xen and KVM.

openSUSE Leap with Xen or KVM acts as a virtualization host server (*VHS*) that supports VM Guests with its own guest operating systems. The SUSE VM Guest architecture consists of a hypervisor and management components that constitute the VHS, which runs many application-hosting VM Guests.

In Xen, the management components run in a privileged VM Guest often called *Dom0*. In KVM, where the Linux kernel acts as the hypervisor, the management components run directly on the VHS.

1.2 Virtualization benefits

Virtualization brings a lot of advantages while providing the same service as a hardware server.

First, it reduces the cost of your infrastructure. Servers are mainly used to provide a service to a customer, and a virtualized operating system can provide the same service, with:

- Less hardware: you can run several operating systems on a single host, therefore all hardware maintenance is reduced.
- Less power/cooling: less hardware means you do not need to invest more in electric power, backup power, and cooling if you need more service.
- Save space: your data center space is saved because you do not need more hardware servers (less servers than service running).
- Less management: using a VM Guest simplifies the administration of your infrastructure.
- Agility and productivity: Virtualization provides *migration* capabilities, *live migration* and *snapshots*. These features reduce downtime, and bring an easy way to move your service from one place to another without any service interruption.

1.3 Virtualization modes

Guest operating systems are hosted on virtual machines in either full virtualization (FV) mode or paravirtual (PV) mode. Each virtualization mode has advantages and disadvantages.

- Full virtualization mode lets virtual machines run unmodified operating systems, such as Windows* Server 2003. It can use either Binary Translation or *hardware-assisted* virtualization technology, such as AMD* Virtualization or Intel* Virtualization Technology. Using hardware assistance allows for better performance on processors that support it.
- To be able to run under paravirtual mode, guest operating systems normally need to be modified for the virtualization environment. However, operating systems running in paravirtual mode have better performance than those running under full virtualization. Operating systems currently modified to run in paravirtual mode are called *paravirtualized operating systems* and include openSUSE Leap.

1.4 I/O virtualization

VM Guests not only share CPU and memory resources of the host system, but also the I/O subsystem. Because software I/O virtualization techniques deliver less performance than bare metal, hardware solutions that deliver almost “native” performance have been developed recently. openSUSE Leap supports the following I/O virtualization techniques:

Full virtualization

Fully Virtualized (FV) drivers emulate widely supported real devices, which can be used with an existing driver in the VM Guest. The guest is also called *Hardware Virtual Machine* (HVM). Since the physical device on the VM Host Server may differ from the emulated one, the hypervisor needs to process all I/O operations before handing them over to the physical device. Therefore all I/O operations need to traverse two software layers, a process that not only significantly impacts I/O performance, but also consumes CPU time.

Paravirtualization

Paravirtualization (PV) allows direct communication between the hypervisor and the VM Guest. With less overhead involved, performance is much better than with full virtualization. However, paravirtualization requires either the guest operating system to be modified to support the paravirtualization API or paravirtualized drivers.

PVHVM

This type of virtualization enhances HVM (see *Full virtualization*) with paravirtualized (PV) drivers, and PV interrupt and timer handling.

VFIO

VFIO stands for *Virtual Function I/O* and is a new user-level driver framework for Linux. It replaces the traditional KVM PCI Pass-Through device assignment. The VFIO driver exposes direct device access to user space in a secure memory (*IOMMU*) protected environment. With VFIO, a VM Guest can directly access hardware devices on the VM Host Server (pass-through), avoiding performance issues caused by emulation in performance critical paths. This method does not allow to share devices—each device can only be assigned to a single VM Guest. VFIO needs to be supported by the VM Host Server CPU, chipset and the BIOS/EFI.

Compared to the legacy KVM PCI device assignment, VFIO has the following advantages:

- Resource access is compatible with UEFI Secure Boot.
- Device is isolated and its memory access protected.

- Offers a user space device driver with more flexible device ownership model.
- Is independent of KVM technology, and not bound to x86 architecture only.

In openSUSE Leap the USB and PCI pass-through methods of device assignment are considered deprecated and are superseded by the VFIO model.

SR-IOV

The latest I/O virtualization technique, Single Root I/O Virtualization SR-IOV combines the benefits of the aforementioned techniques—performance and the ability to share a device with several VM Guests. SR-IOV requires special I/O devices, that are capable of replicating resources so they appear as multiple separate devices. Each such “pseudo” device can be directly used by a single guest. However, for network cards for example the number of concurrent queues that can be used is limited, potentially reducing performance for the VM Guest compared to paravirtualized drivers. On the VM Host Server, SR-IOV must be supported by the I/O device, the CPU and chipset, the BIOS/EFI and the hypervisor—for setup instructions see *Section 13.12, “Assigning a host PCI device to a VM Guest”*.

Important: Requirements for VFIO and SR-IOV

To be able to use the VFIO and SR-IOV features, the VM Host Server needs to fulfill the following requirements:

- IOMMU needs to be enabled in the BIOS/EFI.
- For Intel CPUs, the kernel parameter `intel_iommu=on` needs to be provided on the kernel command line. For more information, see https://github.com/torvalds/linux/blob/master/Documentation/admin-guide/kernel-parameters.txt#L1951 ↗.
- The VFIO infrastructure needs to be available. This can be achieved by loading the kernel module `vfio_pci`. For more information, see *Book “Reference”, Chapter 10 “The `systemd` daemon”, Section 10.6.4 “Loading kernel modules”*.

2 Virtualization scenarios

Virtualization provides several useful capabilities to your organization, for example:

- more efficient hardware usage
- support for legacy software
- operating system isolation
- live migration
- disaster recovery
- load balancing

2.1 Server consolidation

Many servers can be replaced by one big physical server, so that hardware is consolidated, and guest operating systems are converted to virtual machines. This also supports running legacy software on new hardware.

- Better usage of resources that were not running at 100%
- Fewer server locations needed
- More efficient use of computer resources: multiple workloads on the same server

- Simplification of data center infrastructure
- Simplifies moving workloads to other hosts, avoiding service downtime
- Faster and agile virtual machine provisioning
- Multiple guest operating systems can run on a single host

Important

Server consolidation requires special attention to the following points:

- Maintenance windows should be carefully planned
- Storage is key: it must be able to support migration and growing disk usage
- You must verify that your servers can support the additional workloads

2.2 Isolation

Guest operating systems are fully isolated from the host running them. Therefore, if there are problems inside virtual machines, the host is not harmed. Also, problems inside one VM do not affect other VMs. No data is shared between VMs.

- UEFI Secure Boot can be used for VMs.
- KSM should be avoided. For more details on KSM, refer to *KSM*.
- Individual CPU cores can be assigned to VMs.
- Hyper-threading (HT) should be disabled to avoid potential security issues.
- VM should not share network, storage, or network hardware.
- Use of advanced hypervisor features such as PCI pass-through or NUMA adversely affects VM migration capabilities.
- Use of paravirtualization and `virtio` drivers improves VM performance and efficiency.

AMD provides specific features regarding the security of virtualization.

2.3 Disaster recovery

The hypervisor can make snapshots of VMs, enabling restoration to a known good state, or to any desired earlier state. Since *Virtualized* OSes are less dependent on hardware configuration than those running directly on bare metal, these snapshots can be restored onto different server hardware so long as it is running the same hypervisor.

2.4 Dynamic load balancing

Live migration provides a simple way to load-balance your services across your infrastructure, by moving VMs from busy hosts to those with spare capacity, on demand.

3 Introduction to Xen virtualization

This chapter introduces and explains the components and technologies you need to understand to set up and manage a Xen-based virtualization environment.

3.1 Basic components

The basic components of a Xen-based virtualization environment are the following:

- Xen hypervisor
- Dom0
- any number of other VM Guests
- tools, commands and configuration files to manage virtualization

Collectively, the physical computer running all these components is called a *VM Host Server* because together these components form a platform for hosting virtual machines.

The Xen hypervisor

The Xen hypervisor, sometimes simply called a virtual machine monitor, is an open source software program that coordinates the low-level interaction between virtual machines and physical hardware.

The Dom0

The virtual machine host environment, also called *Dom0* or controlling domain, is composed of several components, such as:

- openSUSE Leap provides a graphical and a command line environment to manage the virtual machine host components and its virtual machines.

Note

The term “Dom0” refers to a special domain that provides the management environment. This may be run either in graphical or in command line mode.

- The xl tool stack based on the xenlight library (libxl). Use it to manage Xen guest domains.

- QEMU—an open source software that emulates a full computer system, including a processor and multiple peripherals. It provides the ability to host operating systems in both full virtualization or paravirtualization mode.

Xen-based virtual machines

A Xen-based virtual machine, also called a *`VM Guest`* or *`DomU`*, consists of the following components:

- At least one virtual disk that contains a bootable operating system. The virtual disk can be based on a file, partition, volume, or other type of block device.

- A configuration file for each guest domain. It is a text file following the syntax described in the manual page **`man 5 xl.conf`**.

- Several network devices, connected to the virtual network provided by the controlling domain.

Management tools, commands, and configuration files

There is a combination of GUI tools, commands and configuration files to help you manage and customize your virtualization environment.

3.2 Xen virtualization architecture

The following graphic depicts a virtual machine host with four virtual machines. The Xen hypervisor is shown as running directly on the physical hardware platform. Note that the controlling domain is also a virtual machine, although it has several additional management tasks compared to all the other virtual machines.

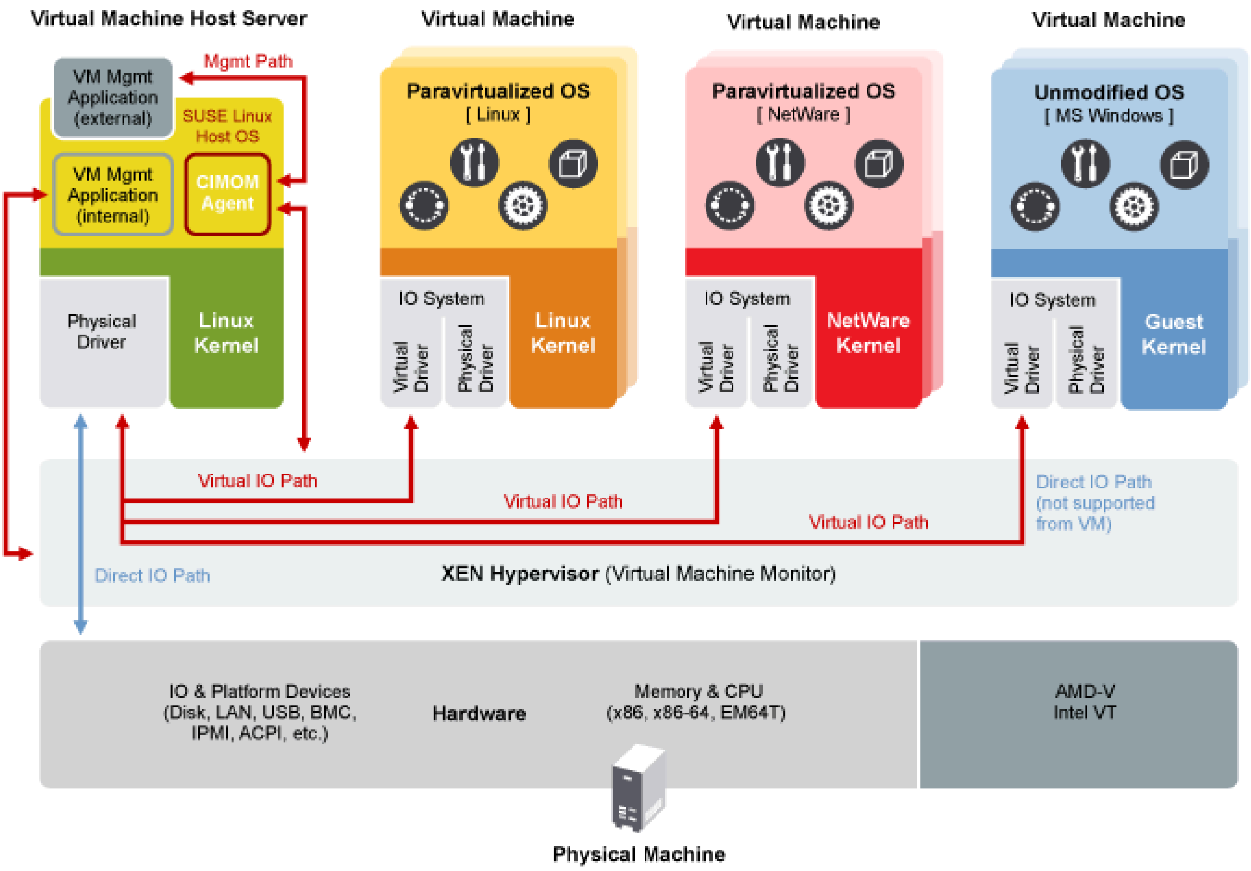


FIGURE 3.1: XEN VIRTUALIZATION ARCHITECTURE

On the left, the virtual machine host's Dom0 is shown running the openSUSE Leap operating system. The two virtual machines shown in the middle are running paravirtualized operating systems. The virtual machine on the right shows a fully virtual machine running an unmodified operating system, such as the latest version of Microsoft Windows/Server.

4 Introduction to KVM virtualization

4.1 Basic components

KVM is a full virtualization solution for hardware architectures that support hardware virtualization.

VM Guests (virtual machines), virtual storage and virtual networks can be managed with QEMU tools directly or with the `libvirt`-based stack. The QEMU tools include **`qemu-system-ARCH`**, the QEMU monitor, **`qemu-img`**, and **`qemu-ndb`**. A `libvirt`-based stack includes `libvirt` itself, along with `libvirt`-based applications such as **`virsh`**, **`virt-manager`**, **`virt-install`**, and **`virt-viewer`**.

4.2 KVM virtualization architecture

This full virtualization solution consists of two main components:

- A set of kernel modules (`kvm.ko`, `kvm-intel.ko`, and `kvm-amd.ko`) that provides the core virtualization infrastructure and processor-specific drivers.
- A user space program (`qemu-system-ARCH`) that provides emulation for virtual devices and control mechanisms to manage VM Guests (virtual machines).

The term KVM more properly refers to the kernel level virtualization functionality, but is in practice more commonly used to refer to the user space component.

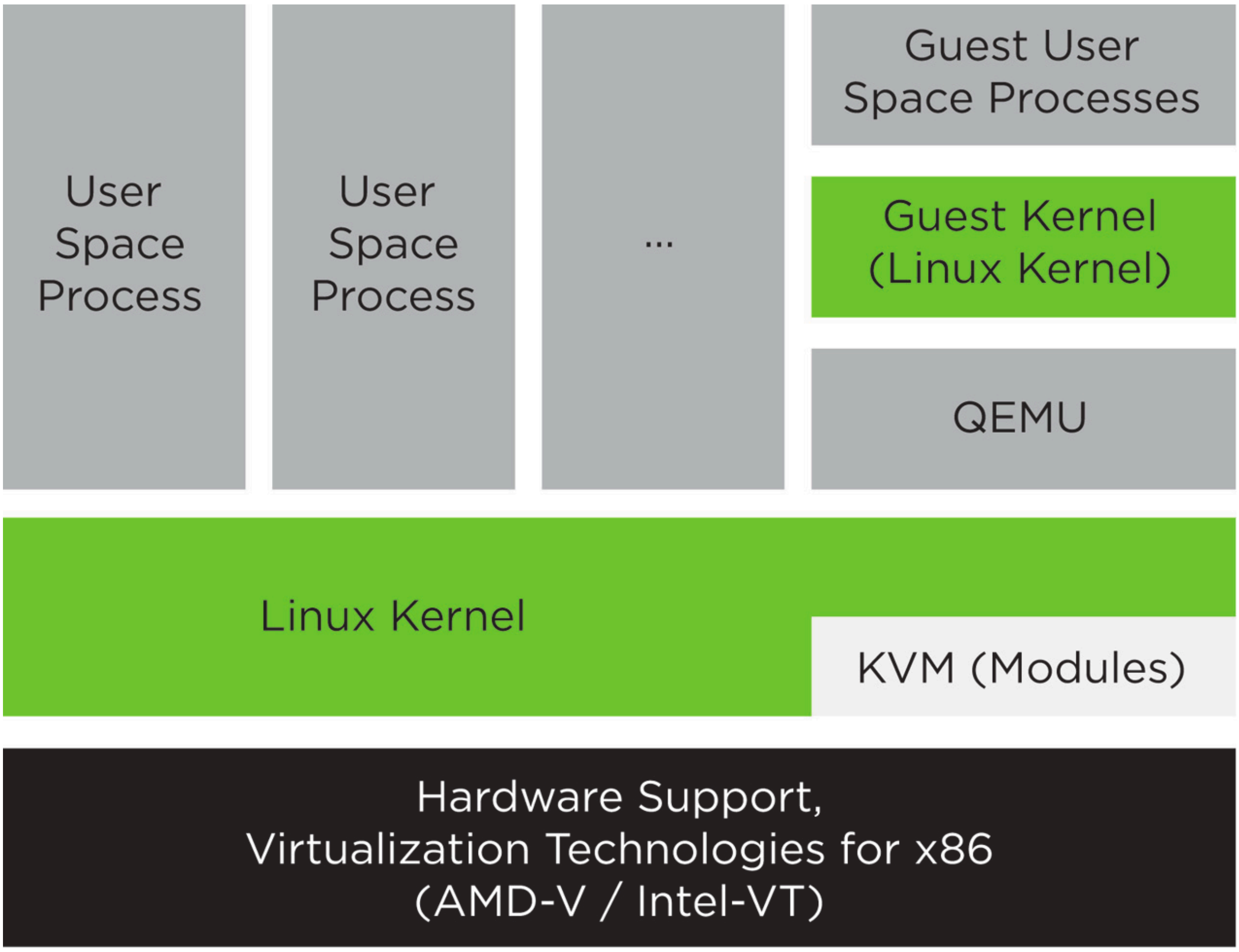

User Space Process
User Space Process
...
Guest User Space Processes
Guest Kernel (Linux Kernel)
QEMU
Linux Kernel
KVM (Modules)
Hardware Support, Virtualization Technologies for x86 (AMD-V / Intel-VT)

FIGURE 4.1: KVM VIRTUALIZATION ARCHITECTURE

5 Virtualization tools

libvirt is a library that provides a common API for managing popular virtualization solutions, among them KVM and Xen. The library provides a normalized management API for these virtualization solutions, allowing a stable, cross-hypervisor interface for higher-level management tools. The library also provides APIs for management of virtual networks and storage on the VM Host Server. The configuration of each VM Guest is stored in an XML file.

With libvirt, you can also manage your VM Guests remotely. It supports TLS encryption, x509 certificates and authentication with SASL. This enables managing VM Host Servers centrally from a single workstation, alleviating the need to access each VM Host Server individually.

Using the libvirt-based tools is the recommended way of managing VM Guests. Interoperability between libvirt and libvirt-based applications has been tested and is an essential part of SUSE's support stance.

5.1 Virtualization console tools

libvirt includes several command-line utilities to manage virtual machines. The most important ones are:

virsh (Package: libvirt-client)

A command-line tool to manage VM Guests with similar functionality as the Virtual Machine Manager. **virsh** allows you to change a VM Guest's status, set up new guests and devices, or edit existing configurations. **virsh** is also useful to script VM Guest management operations.

virsh takes the first argument as a command and further arguments as options to this command:

```
virsh [-c URI] COMMAND DOMAIN-ID [OPTIONS]
```

Like **zypper**, **virsh** can also be called without a command. In this case it starts a shell waiting for your commands. This mode is useful when having to run subsequent commands:

```
~> virsh -c qemu+ssh://wilber@mercury.example.com/system
Enter passphrase for key '/home/wilber/.ssh/id_rsa':
Welcome to virsh, the virtualization interactive terminal.

Type:  'help' for help with commands
       'quit' to quit

virsh # hostname
mercury.example.com
```

virt-install (Package: `virt-install`)

A command-line tool for creating new VM Guests using the `libvirt` library. It supports graphical installations via VNC or *SPICE* protocols. Given suitable command-line arguments, **virt-install** can run unattended. This allows for easy automation of guest installs. **virt-install** is the default installation tool used by the Virtual Machine Manager.

remote-viewer (Package: `virt-viewer`)

A simple viewer of a remote desktop. It supports SPICE and VNC protocols.

virt-clone (Package: `virt-install`)

A tool for cloning existing virtual machine images using the `libvirt` hypervisor management library.

virt-host-validate (Package: `libvirt-client`)

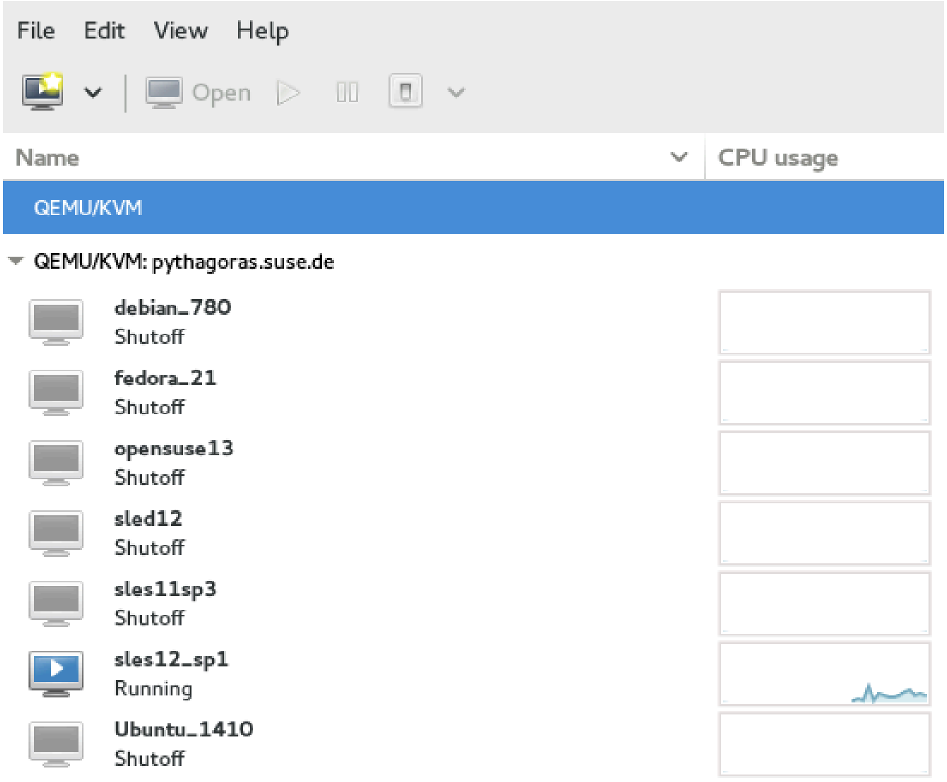
A tool that validates whether the host is configured in a suitable way to run `libvirt` hypervisor drivers.

5.2 Virtualization GUI tools

The following libvirt-based graphical tools are available on openSUSE Leap. All tools are provided by packages carrying the tool's name.

Virtual Machine Manager (package: `virt-manager`)

The Virtual Machine Manager is a desktop tool for managing VM Guests. It provides the ability to control the lifecycle of existing machines (start/shutdown, pause/resume, save/restore) and create new VM Guests. It allows managing multiple types of storage and virtual networks. It provides access to the graphical console of VM Guests with a built-in VNC viewer and can be used to view performance statistics. **`virt-manager`** supports connecting to a local `libvirtd`, managing a local VM Host Server, or a remote `libvirtd` managing a remote VM Host Server.



QEMU/KVM

QEMU/KVM: pythagoras.suse.de

Name	CPU usage
debian_780 Shutoff	
fedora_21 Shutoff	
opensuse13 Shutoff	
sled12 Shutoff	
sles11sp3 Shutoff	
sles12_sp1 Running	
Ubuntu_1410 Shutoff	

To start the Virtual Machine Manager, enter **`virt-manager`** at the command prompt.

Note

To disable automatic USB device redirection for VM Guest using spice, either launch **`virt-manager`** with the `--spice-disable-auto-usbredir` parameter or run the following command to persistently change the default behavior:

```
> dconf write /org/virt-manager/virt-manager/console/auto-redirect false
```

`virt-viewer` (Package: `virt-viewer`)

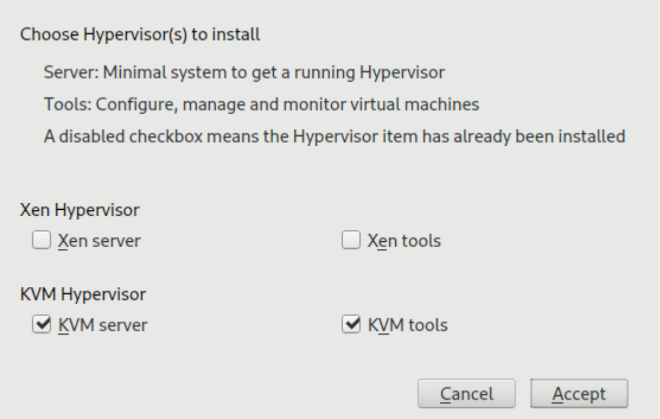
A viewer for the graphical console of a VM Guest. It uses SPICE (configured by default on the VM Guest) or VNC protocols and supports TLS and x509 certificates. VM Guests can be accessed by name, ID or UUID. If the guest is not already running, the viewer can be told to wait until the guest starts, before attempting to connect to the console. **`virt-viewer`** is not installed by default and is available after installing the package `virt-viewer`.

Note

To disable automatic USB device redirection for VM Guest using spice, add an empty filter using the `--spice-usbredir-auto-redirect-filter=''` parameter.

`yast2 vm` (Package: `yast2-vm`)

A YaST module that simplifies the installation of virtualization tools and can set up a network bridge:



Choose Hypervisor(s) to install

Server: Minimal system to get a running Hypervisor

Tools: Configure, manage and monitor virtual machines

A disabled checkbox means the Hypervisor item has already been installed

Xen Hypervisor

□ Xen server □ Xen tools

KVM Hypervisor

☑ KVM server ☑ KVM tools

6 Installation of virtualization components

6.1 Introduction

To run a virtualization server (VM Host Server) that can host one or more guest systems (VM Guests), you need to install required virtualization components on the server. These components vary depending on which virtualization technology you want to use.

6.2 Installing virtualization components

You can install the virtualization tools required to run a VM Host Server in one of the following ways:

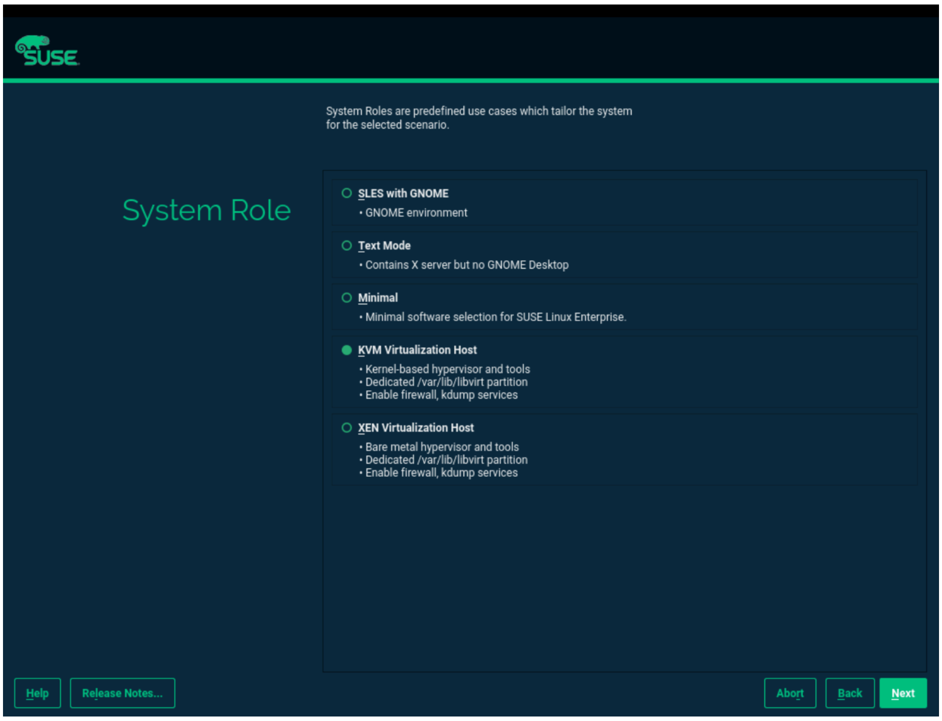
- By selecting a specific system role during openSUSE Leap installation on the VM Host Server

- By running the *YaST Virtualization* module on an already installed and running openSUSE Leap.

- By installing specific installation patterns on an already installed and running openSUSE Leap.

6.2.1 Specifying a system role

You can install all the tools required for virtualization during the installation of openSUSE Leap on the VM Host Server. During the installation, you are presented with the *System Role* screen.



System Roles are predefined use cases which tailor the system for the selected scenario.

System Role

○ SLES with GNOME
- GNOME environment

○ Text Mode
- Contains X server but no GNOME Desktop

○ Minimal
- Minimal software selection for SUSE Linux Enterprise.

● KVM Virtualization Host
- Kernel-based hypervisor and tools
- Dedicated /var/lib/libvirt partition
- Enable firewall, kdump services

○ XEN Virtualization Host
- Bare metal hypervisor and tools
- Dedicated /var/lib/libvirt partition
- Enable firewall, kdump services

FIGURE 6.1: SYSTEM ROLE SCREEN

Here you can select either the *KVM Virtualization Host* or the *Xen Virtualization Host* roles. The appropriate software selection and setup is automatically performed during openSUSE Leap installation.

Tip

Both virtualization system roles create a dedicated `/var/lib/libvirt` partition, and enable the `firewalld` and Kdump services.

6.2.2 Running the *YaST Virtualization* module

Depending on the scope of openSUSE Leap installation on the VM Host Server, none of the virtualization tools may be installed on your system. They are automatically installed when configuring the hypervisor with the *YaST Virtualization* module.

Tip

The *YaST Virtualization* module is included in the `yast2-vm` package. Verify it is installed on the VM Host Server before installing virtualization components.

PROCEDURE 6.1: INSTALLING THE KVM ENVIRONMENT

To install the KVM virtualization environment and related tools, proceed as follows:

1. Start YaST and select *Virtualization* › *Install Hypervisor and Tools*.
2. Select *KVM server* for a minimal installation of QEMU and KVM environment. Select *KVM tools* if you want to use the `libvirt`-based management stack as well. Confirm with *Accept*.
3. YaST offers to automatically configure a network bridge on the VM Host Server. It ensures proper networking capabilities of the VM Guest. Agree to do so by selecting *Yes*, otherwise choose *No*.
4. After the setup has been finished, you can start creating and configuring VM Guests. Rebooting the VM Host Server is not required.

PROCEDURE 6.2: INSTALLING THE XEN ENVIRONMENT

To install the Xen virtualization environment, proceed as follows:

1. Start YaST and select*Virtualization* › *Install Hypervisor and Tools*.
2. Select *Xen server* for a minimal installation of Xen environment. Select *Xen tools* to use the `libvirt`-based management stack as well. Confirm with *Accept*.
3. YaST offers to automatically configure a network bridge on the VM Host Server. It ensures proper networking capabilities of the VM Guest. Agree to do so by selecting *Yes*, otherwise choose *No*.
4. After the setup has been finished, you need to reboot the machine with the *Xen kernel*.

Tip: Default boot kernel

If everything works as expected, change the default boot kernel with YaST and make the Xen-enabled kernel the default. For more information about changing the default kernel, see *Book “Reference”, Chapter 12 “The boot loader GRUB 2”, Section 12.3 “Configuring the boot loader with YaST”*.

6.2.3 Installing specific installation patterns

Related software packages from openSUSE Leap software repositories are organized into *installation patterns*. You can use these patterns to install specific virtualization components on an already running openSUSE Leap. Use **zypper** to install them:

```
zypper install -t pattern PATTERN_NAME
```

To install the KVM environment, consider the following patterns:

`kvm_server`
: Installs basic VM Host Server with the KVM and QEMU environments.

`kvm_tools`
: Installs `libvirt` tools for managing and monitoring VM Guests in KVM environment.

To install the Xen environment, consider the following patterns:

`xen_server`
: Installs a basic Xen VM Host Server.

`xen_tools`
: Installs `libvirt` tools for managing and monitoring VM Guests in Xen environment.

6.3 Installing UEFI support

Note

We support UEFI Secure Boot on AMD64/Intel 64 guests only. KVM guests support UEFI Secure Boot by using the OVMF firmware. Xen HVM guests support booting from the OVMF firmware as well, but they do not support UEFI Secure Boot.

UEFI support is provided by *OVMF* (*Open Virtual Machine Firmware*). To enable UEFI boot, first install the `qemu-ovmf-x86_64` or `qemu-uefi-aarch64` package depending on the architecture of the guest.

The firmware used by virtual machines is auto-selected. The auto-selection is based on the JSON files in the firmware package described above. The `libvirt` QEMU driver parses those files during loading to know the capabilities of multiple types of firmware. Then when the user selects the type of firmware and any desired features (for example, support for UEFI Secure Boot), `libvirt` can find a firmware file that satisfies the user's requirements.

For example, to specify EFI with UEFI Secure Boot, use the following configuration:

```
<os firmware='efi'>
 <loader secure='yes'/>
</os>
```

The `qemu-ovmf-x86_64` package contains the following important UEFI firmware images. They provide UEFI Secure Boot capability for VM Guests:

```
# rpm -ql qemu-ovmf-x86_64
[...]
/usr/share/qemu/ovmf-x86_64-smm-ms-code.bin
/usr/share/qemu/ovmf-x86_64-smm-ms-vars.bin
/usr/share/qemu/ovmf-x86_64-smm-opensuse-code.bin
/usr/share/qemu/ovmf-x86_64-smm-opensuse-vars.bin
/usr/share/qemu/ovmf-x86_64-smm-suse-code.bin
/usr/share/qemu/ovmf-x86_64-smm-suse-vars.bin
[...]
```

- To use UEFI Secure Boot for SUSE Linux Enterprise guests, use the `ovmf-x86_64-smm-suse-code.bin` firmware.
- To use UEFI Secure Boot for openSUSE guests, use the `ovmf-x86_64-smm-opensuse-code.bin` firmware.
- To use UEFI Secure Boot for Microsoft Windows guests, use the `ovmf-x86_64-smm-ms-code.bin` firmware.

For the AArch64 architecture, the package is named `qemu-uefi-aarch32`:

```
# rpm -ql qemu-uefi-aarch32
[...]
/usr/share/qemu/aavmf-aarch32-code.bin
/usr/share/qemu/aavmf-aarch32-vars.bin
/usr/share/qemu/firmware
/usr/share/qemu/firmware/60-aavmf-aarch32.json
/usr/share/qemu/qemu-uefi-aarch32.bin
```

The `*-code.bin` files are the UEFI firmware files. The `*-vars.bin` files are corresponding variable store images that can be used as a template for a per-VM non-volatile store. `libvirt` copies the specified `vars` template to a per-VM path under `/var/lib/libvirt/qemu/nvram/` when first creating the VM. Files without `code` or `vars` in the name can be used as a single UEFI image. They are not as useful since no UEFI variables persist across power cycles of the VM.

The `*-ms*.bin` files contain UEFI CA keys as found on real hardware. Therefore, they are configured as the default in `libvirt`. Likewise, the `*-suse*.bin` files contain preinstalled SUSE keys. There is also a set of files with no preinstalled keys.

For details, see *Using UEFI Secure Boot* and http://www.linux-kvm.org/downloads/lersek/ovmf-whitepaper-c770f8c.txt ↗.

6.4 Enable nested virtualization in KVM

! Important: Technology preview

KVM's nested virtualization is still a technology preview. It is provided for testing purposes and is not supported.

Nested guests are KVM guests run in a KVM guest. When describing nested guests, we use the following virtualization layers:

L0

A bare metal host running KVM.

L1

A virtual machine running on L0. Because it can run another KVM, it is called a *guest hypervisor*.

L2

A virtual machine running on L1. It is called a *nested guest*.

Nested virtualization has many advantages. You can benefit from it in the following scenarios:

- Manage your own virtual machines directly with your hypervisor of choice in cloud environments.
- Enable the live migration of hypervisors and their guest virtual machines as a single entity.

Note

Live migration of a nested VM Guest is not supported.

- Use it for software development and testing.

To enable nesting temporarily, remove the module and reload it with the `nested` KVM module parameter:

- For Intel CPUs, run:

```
> sudo modprobe -r kvm_intel && modprobe kvm_intel nested=1
```

- For AMD CPUs, run:

```
> sudo modprobe -r kvm_amd && modprobe kvm_amd nested=1
```

To enable nesting permanently, enable the `nested` KVM module parameter in the `/etc/modprobe.d/kvm_*.conf` file, depending on your CPU:

- For Intel CPUs, edit `/etc/modprobe.d/kvm_intel.conf` and add the following line:

```
options kvm_intel nested=1
```

- For AMD CPUs, edit `/etc/modprobe.d/kvm_amd.conf` and add the following line:

```
options kvm_amd nested=1
```

When your L0 host is capable of nesting, you can start an L1 guest in one of the following ways:

- Use the `-cpu host` QEMU command line option.
- Add the `vmx` (for Intel CPUs) or the `svm` (for AMD CPUs) CPU feature to the `-cpu` QEMU command line option, which enables virtualization for the virtual CPU.

6.4.1 VMware ESX as a guest hypervisor

If you use VMware ESX as a guest hypervisor on top of a KVM bare metal hypervisor, you may experience unstable network communication. This problem occurs especially between nested KVM guests and the KVM bare metal hypervisor or external network. The following default CPU configuration of the nested KVM guest is causing the problem:

```
<cpu mode='host-model' check='partial'/>
```

To fix it, modify the CPU configuration as follow:

```
[...]
<cpu mode='host-passthrough' check='none'>
 <cache mode='passthrough'/>
</cpu>
[...]
```

II Managing virtual machines with `libvirt`

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7 libvirt daemons

A libvirt deployment for accessing KVM or Xen requires one or more daemons to be installed and active on the host. libvirt provides two daemon deployment options: monolithic or modular daemons. libvirt has always provided the single monolithic daemon libvirtd. It includes the primary hypervisor drivers and all supporting secondary drivers needed for storage, such as networking, node device and management. The monolithic libvirtd also provides secure remote access for external clients. With modular daemons, each driver runs in its own daemon, allowing users to customize their libvirt deployment. By default, the monolithic daemon is enabled, but a deployment can be switched to modular daemons by managing the corresponding systemd service files.

The modular daemon deployment is useful in scenarios where minimal libvirt support is needed. For example, if virtual machine storage and networking is not provided by libvirt, the libvirt-daemon-driver-storage and libvirt-daemon-driver-network type of packages are not required. Kubernetes is an example of an extreme case, where it handles all networking, storage, cgroups and namespace integration, etc. Only the libvirt-daemon-driver-QEMU package, providing virtqemud, needs to be installed. Modular daemons allow configuring a custom libvirt deployment containing only the components required for the use case.

7.1 Starting and stopping the monolithic daemon

The monolithic daemon is known as libvirtd and is configured via /etc/libvirt/libvirtd.conf. libvirtd is managed with several systemd unit files:

- *libvirtd.service* - The main systemd unit file for launching libvirtd. We recommend configuring libvirtd.service to start on boot if VMs are also configured to start on host boot.
- *libvirtd.socket* - The unit file corresponding to the main read-write UNIX socket /var/run/libvirt/libvirt-sock. We recommend enabling this unit on boot.
- *libvirtd-ro.socket* - The unit file corresponding to the main read-only UNIX socket /var/run/libvirt/libvirt-sock-ro. We recommend enabling this unit on boot.
- *libvirtd-admin.socket* - The unit file corresponding to the administrative UNIX socket /var/run/libvirt/libvirt-admin-sock. We recommend enabling this unit on boot.

- *libvirtd-tcp.socket* - The unit file corresponding to the TCP 16509 port for non-TLS remote access. This unit should not be configured to start on boot until the administrator has configured a suitable authentication mechanism.
- *libvirtd-tls.socket* - The unit file corresponding to the TCP 16509 port for TLS remote access. This unit should not be configured to start on boot until the administrator has deployed x509 certificates and optionally configured a suitable authentication mechanism.

When `systemd` socket activation is used, certain configuration settings in `libvirtd.conf` are no longer honored. Instead, these settings must be controlled via the system unit files:

- *listen_tcp* - TCP socket usage is enabled by starting the `libvirtd-tcp.socket` unit file.
- *listen_tls* - TLS socket usage is enabled by starting the `libvirtd-tls.socket` unit file.
- *tcp_port* - Port for the non-TLS TCP socket, controlled via the `ListenStream` parameter in the `libvirtd-tcp.socket` unit file.
- *tls_port* - Port for the TLS TCP socket, controlled via the `ListenStream` parameter in the `libvirtd-tls.socket` unit file.
- *listen_addr* - IP address to listen on, independently controlled via the `ListenStream` parameter in the `libvirtd-tcp.socket` or `libvirtd-tls.socket` unit files.
- *unix_sock_group* - UNIX socket group owner, controlled via the `SocketGroup` parameter in the `libvirtd.socket` and `libvirtd-ro.socket` unit files.
- *unix_sock_ro_perms* - Read-only UNIX socket permissions, controlled via the `SocketMode` parameter in the `libvirtd-ro.socket` unit file.
- *unix_sock_rw_perms* - Read-write UNIX socket permissions, controlled via the `SocketMode` parameter in the `libvirtd.socket` unit file.
- *unix_sock_admin_perms* - Admin UNIX socket permissions, controlled via the `SocketMode` parameter in the `libvirtd-admin.socket` unit file.
- *unix_sock_dir* - Directory in which all UNIX sockets are created, independently controlled via the `ListenStream` parameter in any of the `libvirtd.socket`, `libvirtd-ro.socket` and `libvirtd-admin.socket` unit files.

Important: Conflicting services: `libvirtd` and `xendomains`

If `libvirtd` fails to start, check if the service `xendomains` is loaded:

```
> systemctl is-active xendomains active
```

If the command returns `active`, you need to stop `xendomains` before you can start the `libvirtd` daemon. If you want `libvirtd` to also start after rebooting, additionally prevent `xendomains` from starting automatically. Disable the service:

```
> sudo systemctl stop xendomains
> sudo systemctl disable xendomains
> sudo systemctl start libvirtd
```

`xendomains` and `libvirtd` provide the same service and when used in parallel, may interfere with one another. As an example, `xendomains` may attempt to start a domU already started by `libvirtd`.

7.2 Starting and stopping the modular daemons

The modular daemons are named after the driver which they are running, with the pattern "virt*DRIVER*d". They are configured via the files `/etc/libvirt/virtDRIVERd.conf`. SUSE supports the virtqemud and virtxend hypervisor daemons, along with all the supporting secondary daemons:

- *virtnetworkd* - The virtual network management daemon which provides `libvirt`'s virtual network management APIs. For example, virtnetworkd can be used to create a NAT virtual network on the host for use by virtual machines.
- *virtnodedevd* - The host physical device management daemon which provides `libvirt`'s node device management APIs. For example, virtnodedevd can be used to detach a PCI device from the host for use by a virtual machine.
- *virtnwfilterd* - The host firewall management daemon which provides `libvirt`'s firewall management APIs. For example, virtnwfilterd can be used to configure network traffic filtering rules for virtual machines.
- *virtsecretd* - The host secret management daemon which provides `libvirt`'s secret management APIs. For example, virtsecretd can be used to store a key associated with a LUKs volume.

- *virtstoraged* - The host storage management daemon which provides `libvirt`'s storage management APIs. virtstoraged can be used to create storage pools and create volumes from those pools.

- *virtinterfaced* - The host NIC management daemon which provides `libvirt`'s host network interface management APIs. For example, virtinterfaced can be used to create a bonded network device on the host. SUSE discourages the use of `libvirt`'s interface management APIs in favor of default networking tools like wicked or NetworkManager. It is recommended to disable virtinterfaced.

- *virtproxyd* - A daemon to proxy connections between the traditional `libvirtd` sockets and the modular daemon sockets. With a modular `libvirt` deployment, virtproxyd allows remote clients to access the `libvirt` APIs similar to the monolithic `libvirtd`. It can also be used by local clients that connect to the monolithic `libvirtd` sockets.

- *virtlogd* - A daemon to manage logs from virtual machine consoles. virtlogd is also used by the monolithic `libvirtd`. The monolithic daemon and virtqemud `systemd` unit files require virtlogd, so it is not necessary to explicitly start virtlogd.

- *virtlockd* - A daemon to manage locks held against virtual machine resources such as disks. virtlockd is also used by the monolithic `libvirtd`. The monolithic daemon, virtqemud, and virtxend `systemd` unit files require virtlockd, so it is not necessary to explicitly start virtlockd.

`libvirt` contains two modular daemons that are also used by the monolithic `libvirtd`, virtlockd and virtlogd.

By default, the modular daemons listen for connections on the `/var/run/libvirt/virtDRIVERd-sock` and `/var/run/libvirt/virtDRIVERd-sock-ro` Unix Domain Sockets. The client library prefers these sockets over the traditional `/var/run/libvirt/libvirtd-sock`. The virtproxyd daemon is available for remote clients or local clients expecting the traditional `libvirtd` socket.

Like the monolithic daemon, the modular daemons are managed with several `systemd` unit files:

- *virt`DRIVER`d.service* - The main unit file for launching the virt`DRIVER`d daemon. We recommend configuring the service to start on boot if VMs are also configured to start on host boot.

- *virt`DRIVER`d.socket* - The unit file corresponding to the main read-write UNIX socket `/var/run/libvirt/virtDRIVERd-sock`. We recommend starting this socket on boot by default.

- *virtDRIVERd-ro.socket* - The unit file corresponding to the main read-only UNIX socket `/var/run/libvirt/virtDRIVERd-sock-ro`. We recommend starting this socket on boot by default.

- *virtDRIVERd-admin.socket* - The unit file corresponding to the administrative UNIX socket `/var/run/libvirt/virtDRIVERd-admin-sock`. We recommend starting this socket on boot by default.

When `systemd` socket activation is used, several configuration settings in virt`DRIVER`d.conf are no longer honored. Instead, these settings must be controlled via the system unit files:

- *unix_sock_group* - UNIX socket group owner, controlled via the `SocketGroup` parameter in the `virtDRIVERd.socket` and `virtDRIVERd-ro.socket` unit files.

- *unix_sock_ro_perms* - Read-only UNIX socket permissions, controlled via the `SocketMode` parameter in the `virtDRIVERd-ro.socket` unit file.

- *unix_sock_rw_perms* - Read-write UNIX socket permissions, controlled via the `SocketMode` parameter in the `virtDRIVERd.socket` unit file.

- *unix_sock_admin_perms* - Admin UNIX socket permissions, controlled via the `SocketMode` parameter in the `virtDRIVERd-admin.socket` unit file.

- *unix_sock_dir* - Directory in which all UNIX sockets are created, independently controlled via the `ListenStream` parameter in any of the `virtDRIVERd.socket`, `virtDRIVERd-ro.socket` and `virtDRIVERd-admin.socket` unit files.

7.3 Switching to modular daemons

Several services need to be changed when switching from the monolithic to modular daemons. It is recommended to stop or evict any running virtual machines before switching between the daemon options.

1. Stop the monolithic daemon and its sockets

   ```
   > sudo systemctl stop libvirtd.service
   > sudo systemctl stop libvirtd{,-ro,-admin}.socket
   ```

2. Disable future start of the monolithic daemon

   ```
   > sudo systemctl disable libvirtd.service
   ```

```
> sudo systemctl disable libvirtd{,-ro,-admin}.socket
```

3. Enable the new daemons for KVM or Xen, including the required secondary drivers. The following example enables the QEMU driver for KVM and all the required secondary drivers:

   ```
   for drv in qemu network nodedev nwfilter secret storage
   do
    > sudo systemctl enable virt${drv}d.service
    > sudo systemctl enable virt${drv}d{,-ro,-admin}.socket
   done
   ```

4. Start the sockets for the same set of daemons

   ```
   for drv in qemu network nodedev nwfilter secret storage
   do
    > sudo systemctl start virt${drv}d{,-ro,-admin}.socket
   done
   ```

5. If connections from remote hosts need to be supported, the virtproxyd daemon must be enabled and started:

   ```
   > sudo systemctl enable virtproxyd.service
   > sudo systemctl enable virtproxyd{,-ro,-admin}.socket
   > sudo systemctl start virtproxyd{,-ro,-admin}.socket
   ```

8 Preparing the VM Host Server

Before you can install guest virtual machines, you need to prepare the VM Host Server to provide the guests with the resources that they need for their operation. Specifically, you need to configure:

- *Networking* so that guests can make use of the network connection provided the host.
- A *storage pool* reachable from the host so that the guests can store their disk images.

8.1 Configuring networks

There are two common network configurations to provide a VM Guest with a network connection:

- A *network bridge*. This is the default and recommended way of providing the guests with network connection.
- A *virtual network* with forwarding enabled.

8.1.1 Network bridge

The network bridge configuration provides a Layer 2 switch for VM Guests, switching Layer 2 Ethernet packets between ports on the bridge based on MAC addresses associated with the ports. This gives the VM Guest Layer 2 access to the VM Host Server's network. This configuration is analogous to connecting the VM Guest's virtual Ethernet cable into a hub that is shared with the host and other VM Guests running on the host. The configuration is often referred to as *shared physical device*.

The network bridge configuration is the default configuration of openSUSE Leap when configured as a KVM or Xen hypervisor. It is the preferred configuration when you simply want to connect VM Guests to the VM Host Server's LAN.

Which tool to use to create the network bridge depends on the service you use to manage the network connection on the VM Host Server:

- If a network connection is managed by `wicked`, use either YaST or the command line to create the network bridge. `wicked` is the default on server hosts.
- If a network connection is managed by NetworkManager, use the NetworkManager command line tool **`nmcli`** to create the network bridge. NetworkManager is the default on desktop and laptops.

8.1.1.1 Managing network bridges with YaST

This section includes procedures to add or remove network bridges with YaST.

8.1.1.1.1 Adding a network bridge

To add a network bridge on VM Host Server, follow these steps:

1. Start *YaST* › *System* › *Network Settings*.
2. Activate the *Overview* tab and click *Add*.
3. Select *Bridge* from the *Device Type* list and enter the bridge device interface name in the *Configuration Name* entry. Click the *Next* button to proceed.
4. In the *Address* tab, specify networking details such as DHCP/static IP address, subnet mask or host name.
   Using *Dynamic Address* is only useful when also assigning a device to a bridge that is connected to a DHCP server.
   If you intend to create a virtual bridge that has no connection to a real network device, use *Statically assigned IP Address*. In this case, it is a good idea to use addresses from the private IP address ranges, for example, `192.168.0.0/16`, `172.16.0.0/12`, or `10.0.0.0/8`.
   To create a bridge that should only serve as a connection between the different guests without connection to the host system, set the IP address to `0.0.0.0` and the subnet mask to `255.255.255.255`. The network scripts handle this special address as an unset IP address.
5. Activate the *Bridged Devices* tab and activate the network devices you want to include in the network bridge.

6. Click *Next* to return to the *Overview* tab and confirm with *OK*. The new network bridge should now be active on VM Host Server.

8.1.1.1.2 Deleting a network bridge

To delete an existing network bridge, follow these steps:

1. Start *YaST* › *System* › *Network Settings*.

2. Select the bridge device you want to delete from the list in the *Overview* tab.

3. Delete the bridge with *Delete* and confirm with *OK*.

8.1.1.2 Managing network bridges from the command line

This section includes procedures to add or remove network bridges using the command line.

8.1.1.2.1 Adding a network bridge

To add a new network bridge device on VM Host Server, follow these steps:

1. Log in as `root` on the VM Host Server where you want to create a new network bridge.

2. Choose a name for the new bridge—*`virbr_test`* in our example—and run

   ```
   # ip link add name VIRBR_TEST type bridge
   ```

3. Check if the bridge was created on VM Host Server:

   ```
   # bridge vlan
   [...]
   virbr_test  1 PVID Egress Untagged
   ```

   `virbr_test` is present, but is not associated with any physical network interface.

4. Bring the network bridge up and add a network interface to the bridge:

   ```
   # ip link set virbr_test up
   # ip link set eth1 master virbr_test
   ```

> **!** Important: Network interface must be unused
>
> You can only assign a network interface that is not yet used by another network bridge.

5. Optionally, enable STP (see Spanning Tree Protocol (https://en.wikipedia.org/wiki/Spanning_Tree_Protocol) ↗):

```
# bridge link set dev virbr_test cost 4
```

8.1.1.2.2 Deleting a network bridge

To delete an existing network bridge device on VM Host Server from the command line, follow these steps:

1. Log in as `root` on the VM Host Server where you want to delete an existing network bridge.

2. List existing network bridges to identify the name of the bridge to remove:

```
# bridge vlan
[...]
virbr_test  1 PVID Egress Untagged
```

3. Delete the bridge:

```
# ip link delete dev virbr_test
```

8.1.1.3 Adding a network bridge with **`nmcli`**

This section includes procedures to add a network bridge with NetworkManager's command line tool **`nmcli`**.

1. List active network connections:

```
> sudo nmcli connection show --active
NAME                   UUID                                  TYPE      DEVICE
Ethernet connection 1  84ba4c22-0cfe-46b6-87bb-909be6cb1214  ethernet  eth0
```

2. Add a new bridge device named `br0` and verify its creation:

   ```
   > sudo nmcli connection add type bridge ifname br0
   Connection 'bridge-br0' (36e11b95-8d5d-4a8f-9ca3-ff4180eb89f7) \
   successfully added.
   > sudo nmcli connection show --active
   NAME                   UUID                                  TYPE      DEVICE
   bridge-br0             36e11b95-8d5d-4a8f-9ca3-ff4180eb89f7  bridge    br0
   Ethernet connection 1  84ba4c22-0cfe-46b6-87bb-909be6cb1214  ethernet  eth0
   ```

3. Optionally, you can view the bridge settings:

   ```
   > sudo nmcli -f bridge connection show bridge-br0
   bridge.mac-address:                     --
   bridge.stp:                             yes
   bridge.priority:                        32768
   bridge.forward-delay:                   15
   bridge.hello-time:                      2
   bridge.max-age:                         20
   bridge.ageing-time:                     300
   bridge.group-forward-mask:              0
   bridge.multicast-snooping:              yes
   bridge.vlan-filtering:                  no
   bridge.vlan-default-pvid:               1
   bridge.vlans:                           --
   ```

4. Link the bridge device to the physical Ethernet device `eth0`:

   ```
   > sudo nmcli connection add type bridge-slave ifname eth0 master br0
   ```

5. Disable the `eth0` interface and enable the new bridge:

   ```
   > sudo nmcli connection down "Ethernet connection 1"
   > sudo nmcli connection up bridge-br0
   Connection successfully activated (master waiting for slaves) \
   (D-Bus active path: /org/freedesktop/NetworkManager/ActiveConnection/9)
   ```

8.1.1.4 Using VLAN interfaces

Sometimes it is necessary to create a private connection either between two VM Host Servers or between VM Guest systems. For example, to migrate a VM Guest to hosts in a different network segment. Or to create a private bridge that only VM Guest systems may connect to (even when running on different VM Host Server systems). An easy way to build such connections is to set up VLAN networks.

VLAN interfaces are commonly set up on the VM Host Server. They either interconnect the different VM Host Server systems, or they may be set up as a physical interface to an otherwise virtual-only bridge. It is even possible to create a bridge with a VLAN as a physical interface that has no IP address in the VM Host Server. That way, the guest systems have no possibility to access the host over this network.

Run the YaST module *System* › *Network Settings*. Follow this procedure to set up the VLAN device:

PROCEDURE 8.1: SETTING UP VLAN INTERFACES WITH YAST

1. Click *Add* to create a new network interface.
2. In the *Hardware Dialog*, select *Device Type VLAN*.
3. Change the value of *Configuration Name* to the ID of your VLAN. Be aware VLAN ID `1` is commonly used for management purposes.
4. Click *Next*.
5. Select the interface that the VLAN device should connect to below *Real Interface for VLAN*. If the desired interface does not appear in the list, first set up this interface without an IP address.
6. Select the desired method for assigning an IP address to the VLAN device.
7. Click *Next* to finish the configuration.

It is also possible to use the VLAN interface as a physical interface of a bridge. This makes it possible to connect several VM Host Server-only networks and allows live migration of VM Guest systems that are connected to such a network.

YaST does not always allow setting no IP address. However, this may be a desired feature, especially if VM Host Server-only networks should be connected. In this case, use the special address `0.0.0.0` with netmask `255.255.255.255`. The system scripts handle this address as no IP address set.

8.1.2 Virtual networks

`libvirt`-managed virtual networks are similar to bridged networks, but typically have no Layer 2 connection to the VM Host Server. Connectivity to the VM Host Server's physical network is accomplished with Layer 3 forwarding, which introduces additional packet processing on the

VM Host Server as compared to a Layer 2 bridged network. Virtual networks also provide DHCP and DNS services for VM Guests. For more information on `libvirt` virtual networks, see the *Network XML format* documentation at https://libvirt.org/formatnetwork.html.

A standard `libvirt` installation on openSUSE Leap already comes with a predefined virtual network named `default`. It provides DHCP and DNS services for the network, along with connectivity to the VM Host Server's physical network using the network address translation (NAT) forwarding mode. Although it is predefined, the `default` virtual network needs to be explicitly enabled by the administrator. For more information on the forwarding modes supported by `libvirt`, see the *Connectivity* section of the *Network XML format* documentation at https://libvirt.org/formatnetwork.html#elementsConnect.

`libvirt`-managed virtual networks can be used to satisfy a wide range of use cases, but are commonly used on VM Host Servers that have a wireless connection or dynamic/sporadic network connectivity, such as laptops. Virtual networks are also useful when the VM Host Server's network has limited IP addresses, allowing forwarding of packets between the virtual network and the VM Host Server's network. However, most server use cases are better suited for the network bridge configuration, where VM Guests are connected to the VM Host Server's LAN.

Warning: Enabling forwarding mode

Enabling forwarding mode in a `libvirt` virtual network enables forwarding in the VM Host Server by setting `/proc/sys/net/ipv4/ip_forward` and `/proc/sys/net/ipv6/conf/all/forwarding` to 1, which turns the VM Host Server into a router. Restarting the VM Host Server's network may reset the values and disable forwarding. To avoid this behavior, explicitly enable forwarding in the VM Host Server by editing the `/etc/sysctl.conf` file and adding:

```
net.ipv4.ip_forward = 1
```

```
net.ipv6.conf.all.forwarding = 1
```

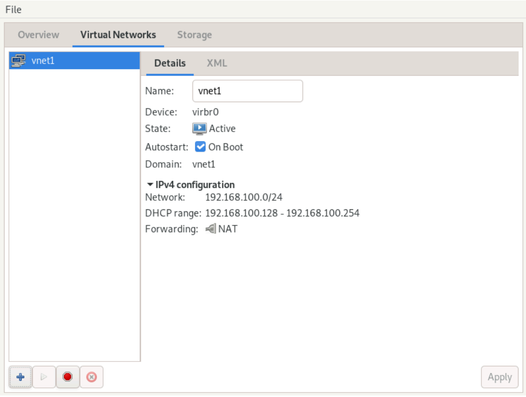
8.1.2.1 Managing virtual networks with Virtual Machine Manager

You can define, configure and operate virtual networks with Virtual Machine Manager.

8.1.2.1.1 Defining virtual networks

1. Start Virtual Machine Manager. In the list of available connections, right-click the name of the connection for which you need to configure the virtual network, and then select *Details*.

2. In the *Connection Details* window, click the *Virtual Networks* tab. You can see the list of all virtual networks available for the current connection. On the right, there are details of the selected virtual network.



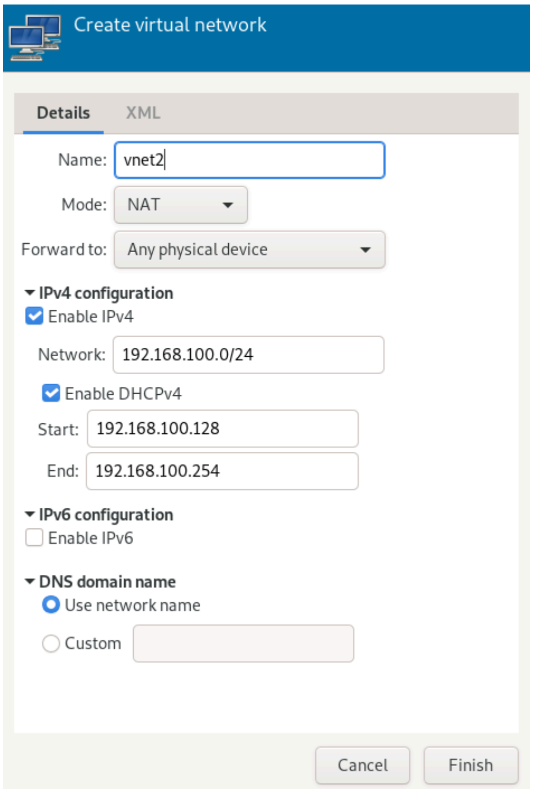
Name: vnet1
Device: virbr0
State: Active
Autostart: ☑ On Boot
Domain: vnet1

IPv4 configuration
Network: 192.168.100.0/24
DHCP range: 192.168.100.128 - 192.168.100.254
Forwarding: NAT

FIGURE 8.1: CONNECTION DETAILS

3. To add a new virtual network, click *Add*.

4. Specify a name for the new virtual network.



Name: vnet2

Mode: NAT

Forward to: Any physical device

IPv4 configuration

☑ Enable IPv4

Network: 192.168.100.0/24

☑ Enable DHCPv4

Start: 192.168.100.128

End: 192.168.100.254

IPv6 configuration

□ Enable IPv6

DNS domain name

● Use network name

○ Custom

FIGURE 8.2: CREATE VIRTUAL NETWORK

5. Specify the networking mode. For the *NAT* and *Routed* types, you can specify to which device to forward network communications. While *NAT* (network address translation) remaps the virtual network address space and allows sharing a single IP address, *Routed* forwards packets from the virtual network to the VM Host Server's physical network with no translation.

6. If you need IPv4 networking, activate *Enable IPv4* and specify the IPv4 network address. If you need a DHCP server, activate *Enable DHCPv4* and specify the assignable IP address range.

7. If you need IPv6 networking, activate *Enable IPv6* and specify the IPv6 network address. If you need a DHCP server, activate *Enable DHCPv6* and specify the assignable IP address range.

8. To specify a different domain name than the name of the virtual network, select *Custom* under *DNS domain name* and enter it here.

9. Click *Finish* to create the new virtual network. On the VM Host Server, a new virtual network bridge `virbrX` is available, which corresponds to the newly created virtual network. You can check with **`bridge link`**. `libvirt` automatically adds iptables rules to allow traffic to/from guests attached to the new *virbr*`X` device.

8.1.2.1.2 Starting virtual networks

To start a virtual network that is temporarily stopped, follow these steps:

1. Start Virtual Machine Manager. In the list of available connections, right-click the name of the connection for which you need to configure the virtual network, and then select *Details*.
2. In the *Connection Details* window, click the *Virtual Networks* tab. You can see the list of all virtual networks available for the current connection.
3. To start the virtual network, click *Start*.

8.1.2.1.3 Stopping virtual networks

To stop an active virtual network, follow these steps:

1. Start Virtual Machine Manager. In the list of available connections, right-click the name of the connection for which you need to configure the virtual network, and then select *Details*.
2. In the *Connection Details* window, click the *Virtual Networks* tab. You can see the list of all virtual networks available for the current connection.
3. Select the virtual network to be stopped, then click *Stop*.

8.1.2.1.4 Deleting virtual networks

To delete a virtual network from VM Host Server, follow these steps:

1. Start Virtual Machine Manager. In the list of available connections, right-click the name of the connection for which you need to configure the virtual network, and then select *Details*.
2. In the *Connection Details* window, click the *Virtual Networks* tab. You can see the list of all virtual networks available for the current connection.
3. Select the virtual network to be deleted, then click *Delete*.

8.1.2.1.5 Obtaining IP addresses with **nsswitch** for NAT networks (in KVM)

- On VM Host Server, install libvirt-nss, which provides NSS support for libvirt:

  ```
  > sudo zypper in libvirt-nss
  ```

- Add `libvirt` to `/etc/nsswitch.conf`:

  ```
  ...
  hosts:  files libvirt mdns_minimal [NOTFOUND=return] dns
  ...
  ```

- If NSCD is running, restart it:

  ```
  > sudo systemctl restart nscd
  ```

Now you can reach the guest system by name from the host.

The NSS module has limited functionality. It reads `/var/lib/libvirt/dnsmasq/*.status` files to find the host name and corresponding IP addresses in a JSON record describing each lease provided by **`dnsmasq`**. Host name translation can only be done on those VM Host Servers using a libvirt-managed bridged network backed by **`dnsmasq`**.

8.1.2.2 Managing virtual networks with **virsh**

You can manage `libvirt`-provided virtual networks with the **`virsh`** command line tool. To view all network related **`virsh`** commands, run

```
> sudo virsh help network
Networking (help keyword 'network'):
 net-autostart                  autostart a network
       net-create                     create a network from an XML file
       net-define                     define (but don't start) a network from an XML
 file
       net-destroy                    destroy (stop) a network
       net-dumpxml                    network information in XML
       net-edit                       edit XML configuration for a network
       net-event                      Network Events
       net-info                       network information
       net-list                       list networks
       net-name                       convert a network UUID to network name
       net-start                      start a (previously defined) inactive network
       net-undefine                   undefine an inactive network
       net-update                     update parts of an existing network's
 configuration
```

```
 net-uuid                      convert a network name to network UUID
```

To view brief help information for a specific `virsh` command, run `virsh help` *`VIRSH_COMMAND`*:

```
> sudo virsh help net-create
  NAME
    net-create - create a network from an XML file

  SYNOPSIS
    net-create <file>

  DESCRIPTION
    Create a network.

  OPTIONS
    [--file] <string>  file containing an XML network description
```

8.1.2.2.1 Creating a network

To create a new *running* virtual network, run

```
> sudo virsh net-create VNET_DEFINITION.xml
```

The *`VNET_DEFINITION.xml`* XML file includes the definition of the virtual network that `libvirt` accepts.

To define a new virtual network without activating it, run

```
> sudo virsh net-define VNET_DEFINITION.xml
```

The following examples illustrate definitions of different types of virtual networks.

EXAMPLE 8.1: NAT-BASED NETWORK

> The following configuration allows VM Guests outgoing connectivity if it is available on the VM Host Server. Without VM Host Server networking, it allows guests to talk directly to each other.

```
<network>
<name>vnet_nated</name>❶
<bridge name="virbr1"/>❷
 <forward mode="nat"/>❸
 <ip address="192.168.122.1" netmask="255.255.255.0">❹
  <dhcp>
   <range start="192.168.122.2" end="192.168.122.254"/>❺
   <host mac="52:54:00:c7:92:da" name="host1.testing.com" \
    ip="192.168.1.101"/>❻
   <host mac="52:54:00:c7:92:db" name="host2.testing.com" \
    ip="192.168.1.102"/>
   <host mac="52:54:00:c7:92:dc" name="host3.testing.com" \
    ip="192.168.1.103"/>
  </dhcp>
 </ip>
</network>
```

❶ The name of the new virtual network.

❷ The name of the bridge device used to construct the virtual network. When defining a new network with a <forward> mode of `"nat"` or `"route"` (or an isolated network with no <forward> element), `libvirt` automatically generates a unique name for the bridge device if none is given.

❸ Inclusion of the <forward> element indicates that the virtual network is connected to the physical LAN. The `mode` attribute specifies the forwarding method. The most common modes are `"nat"` (Network Address Translation, the default), `"route"` (direct forwarding to the physical network, no address translation), and `"bridge"` (network bridge configured outside of `libvirt`). If the <forward> element is not specified, the virtual network is isolated from other networks. For a complete list of forwarding modes, see https://libvirt.org/formatnetwork.html#elementsConnect ↗.

❹ The IP address and netmask for the network bridge.

❺ Enable DHCP server for the virtual network, offering IP addresses ranging from the specified `start` and `end` attributes.

❻ The optional <host> elements specify hosts that are given names and predefined IP addresses by the built-in DHCP server. Any IPv4 host element must specify the following: the MAC address of the host to be assigned a given name, the IP to be assigned to that host, and the name to be given to that host by the DHCP server. An IPv6 host element differs slightly from that for IPv4: there is no `mac` attribute since a MAC address has no defined meaning in IPv6. Instead, the `name` attribute is used to identify the host to be assigned the IPv6 address. For DHCPv6, the `name` is the plain name of the client host sent by the client to the server. This method of assigning a specific IP address can also be used instead of the `mac` attribute for IPv4.

EXAMPLE 8.2: ROUTED NETWORK

The following configuration routes traffic from the virtual network to the LAN without applying any NAT. The IP address range must be preconfigured in the routing tables of the router on the VM Host Server network.

```
<network>
 <name>vnet_routed</name>
 <bridge name="virbr1"/>
 <forward mode="route" dev="eth1"/>❶
 <ip address="192.168.122.1" netmask="255.255.255.0">
  <dhcp>
   <range start="192.168.122.2" end="192.168.122.254"/>
  </dhcp>
 </ip>
</network>
```

❶ The guest traffic may only go out via the `eth1` network device on the VM Host Server.

EXAMPLE 8.3: ISOLATED NETWORK

This configuration provides an isolated private network. The guests can talk to each other, and to VM Host Server, but cannot reach any other machines on the LAN, as the <forward> element is missing in the XML description.

```
<network>
 <name>vnet_isolated</name>
 <bridge name="virbr3"/>
 <ip address="192.168.152.1" netmask="255.255.255.0">
  <dhcp>
   <range start="192.168.152.2" end="192.168.152.254"/>
  </dhcp>
 </ip>
 </network>
```

EXAMPLE 8.4: USING AN EXISTING BRIDGE ON VM HOST SERVER

This configuration shows how to use an existing VM Host Server's network bridge `br0`. VM Guests are directly connected to the physical network. Their IP addresses are all on the subnet of the physical network, and there are no restrictions on incoming or outgoing connections.

```
<network>
        <name>host-bridge</name>
        <forward mode="bridge"/>
        <bridge name="br0"/>
</network>
```

8.1.2.2.2 Listing networks

To list all virtual networks available to `libvirt`, run:

```
> sudo virsh net-list --all

 Name                 State      Autostart     Persistent
----------------------------------------------------------
 crowbar              active     yes           yes
 vnet_nated           active     yes           yes
 vnet_routed          active     yes           yes
 vnet_isolated        inactive   yes           yes
```

To list available domains, run:

```
> sudo virsh list
 Id    Name                               State
----------------------------------------------------
 1     nated_sles12sp3                    running
 ...
```

To get a list of interfaces of a running domain, run `domifaddr DOMAIN`, or optionally specify the interface to limit the output to this interface. By default, it additionally outputs their IP and MAC addresses:

```
> sudo virsh domifaddr nated_sles12sp3 --interface vnet0 --source lease
 Name       MAC address          Protocol     Address
-------------------------------------------------------------------------------
 vnet0      52:54:00:9e:0d:2b    ipv6         fd00:dead:beef:55::140/64
 -          -                    ipv4         192.168.100.168/24
```

To print brief information of all virtual interfaces associated with the specified domain, run:

```
> sudo virsh domiflist nated_sles12sp3
Interface  Type       Source       Model       MAC
---------------------------------------------------------
vnet0      network    vnet_nated   virtio      52:54:00:9e:0d:2b
```

8.1.2.2.3 Getting details about a network

To get detailed information about a network, run:

```
> sudo virsh net-info vnet_routed
Name:           vnet_routed
```

```
UUID:           756b48ff-d0c6-4c0a-804c-86c4c832a498
Active:         yes
Persistent:     yes
Autostart:      yes
Bridge:         virbr5
```

8.1.2.2.4 Starting a network

To start an inactive network that was already defined, find its name (or unique identifier, UUID) with:

```
> sudo virsh net-list --inactive
 Name                 State      Autostart     Persistent
----------------------------------------------------------
 vnet_isolated        inactive   yes           yes
```

Then run:

```
> sudo virsh net-start vnet_isolated
Network vnet_isolated started
```

8.1.2.2.5 Stopping a network

To stop an active network, find its name (or unique identifier, UUID) with:

```
> sudo virsh net-list --inactive
 Name                 State      Autostart     Persistent
----------------------------------------------------------
 vnet_isolated        active     yes           yes
```

Then run:

```
> sudo virsh net-destroy vnet_isolated
Network vnet_isolated destroyed
```

8.1.2.2.6 Removing a network

To remove the definition of an inactive network from VM Host Server permanently, run:

```
> sudo virsh net-undefine vnet_isolated
Network vnet_isolated has been undefined
```

8.2 Configuring a storage pool

When managing a VM Guest on the VM Host Server itself, you can access the complete file system of the VM Host Server to attach or create virtual hard disks or to attach existing images to the VM Guest. However, this is not possible when managing VM Guests from a remote host. For this reason, `libvirt` supports so called “Storage Pools”, which can be accessed from remote machines.

Tip: CD/DVD ISO images

To be able to access CD/DVD ISO images on the VM Host Server from remote clients, they also need to be placed in a storage pool.

`libvirt` knows two different types of storage: volumes and pools.

Storage volume

A storage volume is a storage device that can be assigned to a guest—a virtual disk or a CD/DVD/floppy image. Physically, it can be a block device—for example, a partition or a logical volume—or a file on the VM Host Server.

Storage pool

A storage pool is a storage resource on the VM Host Server that can be used for storing volumes, similar to network storage for a desktop machine. Physically it can be one of the following types:

File system directory (*dir*)

A directory for hosting image files. The files can be either one of the supported disk formats (raw or qcow2), or ISO images.

Physical disk device (*disk*)

Use a complete physical disk as storage. A partition is created for each volume that is added to the pool.

Pre-formatted block device (*fs*)

Specify a partition to be used in the same way as a file system directory pool (a directory for hosting image files). The only difference to using a file system directory is that `libvirt` takes care of mounting the device.

iSCSI target (iscsi)

Set up a pool on an iSCSI target. You need to have been logged in to the volume once before to use it with `libvirt`. Use the YaST *iSCSI Initiator* to detect and log in to a volume. Volume creation on iSCSI pools is not supported; instead, each existing Logical Unit Number (LUN) represents a volume. Each volume/LUN also needs a valid (empty) partition table or disk label before you can use it. If missing, use **`fdisk`** to add it:

```
> sudo fdisk -cu /dev/disk/by-path/ip-192.168.2.100:3260-iscsi-
iqn.2010-10.com.example:[...]-lun-2
Device contains neither a valid DOS partition table, nor Sun, SGI
or OSF disklabel
Building a new DOS disklabel with disk identifier 0xc15cdc4e.
Changes will remain in memory only, until you decide to write them.
After that, of course, the previous content won't be recoverable.

Warning: invalid flag 0x0000 of partition table 4 will be corrected by w(rite)

Command (m for help): w
The partition table has been altered!

Calling ioctl() to re-read partition table.
Syncing disks.
```

LVM volume group (logical)

Use an LVM volume group as a pool. You can either use a predefined volume group, or create a group by specifying the devices to use. Storage volumes are created as partitions on the volume.

Warning: Deleting the LVM-based pool

When the LVM-based pool is deleted in the Storage Manager, the volume group is deleted as well. This results in a non-recoverable loss of all data stored on the pool.

Multipath devices (*mpath*)

At the moment, multipathing support is limited to assigning existing devices to the guests. Volume creation or configuring multipathing from within `libvirt` is not supported.

Network exported directory (*netfs*)

Specify a network directory to be used in the same way as a file system directory pool (a directory for hosting image files). The only difference to using a file system directory is that `libvirt` takes care of mounting the directory. The supported protocol is NFS.

SCSI host adapter (*scsi*)

Use an SCSI host adapter in almost the same way as an iSCSI target. We recommend to use a device name from `/dev/disk/by-*` rather than `/dev/sdX`. The latter can change (for example, when adding or removing hard disks). Volume creation on iSCSI pools is not supported. Instead, each existing LUN (Logical Unit Number) represents a volume.

Warning: Security considerations

To avoid data loss or data corruption, do not attempt to use resources such as LVM volume groups, iSCSI targets, etc., that are also used to build storage pools on the VM Host Server. There is no need to connect to these resources from the VM Host Server or to mount them on the VM Host Server—`libvirt` takes care of this.

Do not mount partitions on the VM Host Server by label. Under certain circumstances it is possible that a partition is labeled from within a VM Guest with a name existing on the VM Host Server.

8.2.1 Managing storage with `virsh`

Managing storage from the command line is also possible by using **`virsh`**. However, creating storage pools is currently not supported by SUSE. Therefore, this section is restricted to documenting functions such as starting, stopping and deleting pools, and volume management.

A list of all **`virsh`** subcommands for managing pools and volumes is available by running **`virsh help pool`** and **`virsh help volume`**, respectively.

8.2.1.1 Listing pools and volumes

List all pools currently active by executing the following command. To also list inactive pools, add the option `--all`:

```
> virsh pool-list --details
```

Details about a specific pool can be obtained with the `pool-info` subcommand:

```
> virsh pool-info POOL
```

By default, volumes can only be listed per pool. To list all volumes from a pool, enter the following command.

```
> virsh vol-list --details POOL
```

At the moment **`virsh`** offers no tools to show whether a volume is used by a guest or not. The following procedure describes a way to list volumes from all pools that are currently used by a VM Guest.

PROCEDURE 8.2: LISTING ALL STORAGE VOLUMES CURRENTLY USED ON A VM HOST SERVER

1. Create an XSLT stylesheet by saving the following content to a file, for example, ~/libvirt/guest_storage_list.xsl:

   ```
   <?xml version="1.0" encoding="UTF-8"?>
   <xsl:stylesheet version="1.0"
     xmlns:xsl="http://www.w3.org/1999/XSL/Transform">
     <xsl:output method="text"/>
     <xsl:template match="text()"/>
     <xsl:strip-space elements="*"/>
     <xsl:template match="disk">
       <xsl:text>  </xsl:text>
       <xsl:value-of select="(source/@file|source/@dev|source/@dir)[1]"/>
       <xsl:text>&#10;</xsl:text>
     </xsl:template>
   </xsl:stylesheet>
   ```

2. Run the following commands in a shell. It is assumed that the guest's XML definitions are all stored in the default location (`/etc/libvirt/qemu`). **`xsltproc`** is provided by the package `libxslt`.

   ```
   SSHEET="$HOME/libvirt/guest_storage_list.xsl"
   ```

```
cd /etc/libvirt/qemu
for FILE in *.xml; do
  basename $FILE .xml
  xsltproc $SSHEET $FILE
done
```

8.2.1.2 Starting, stopping, and deleting pools

Use the **virsh** pool subcommands to start, stop or delete a pool. Replace *POOL* with the pool's name or its UUID in the following examples:

Stopping a pool

```
> virsh pool-destroy POOL
```

Note: A pool's state does not affect attached volumes

Volumes from a pool attached to VM Guests are always available, regardless of the pool's state (*Active* (stopped) or *Inactive* (started)). The state of the pool solely affects the ability to attach volumes to a VM Guest via remote management.

Deleting a pool

```
> virsh pool-delete POOL
```

Warning: Deleting storage pools

See *Warning: Deleting storage pools*

Starting a pool

```
> virsh pool-start POOL
```

Enable autostarting a pool

```
> virsh pool-autostart POOL
```

Only pools that are marked to autostart are automatically started if the VM Host Server reboots.

Disable autostarting a pool

```
> virsh pool-autostart POOL --disable
```

8.2.1.3 Adding volumes to a storage pool

`virsh` offers two ways to add volumes to storage pools: either from an XML definition with `vol-create` and `vol-create-from` or via command line arguments with `vol-create-as`. The first two methods are currently not supported by SUSE, therefore this section focuses on the subcommand `vol-create-as`.

To add a volume to an existing pool, enter the following command:

```
> virsh vol-create-as POOL❶NAME❷ 12G --format❸raw|qcow2❹ --allocation 4G❺
```

❶ Name of the pool to which the volume should be added

❷ Name of the volume

❸ Size of the image, in this example 12 gigabytes. Use the suffixes k, M, G, T for kilobyte, megabyte, gigabyte, and terabyte, respectively.

❹ Format of the volume. SUSE currently supports `raw` and `qcow2`.

❺ Optional parameter. By default, **`virsh`** creates a sparse image file that grows on demand. Specify the amount of space that should be allocated with this parameter (4 gigabytes in this example). Use the suffixes k, M, G, T for kilobyte, megabyte, gigabyte, and terabyte, respectively.
When not specifying this parameter, a sparse image file with no allocation is generated. To create a non-sparse volume, specify the whole image size with this parameter (would be `12G` in this example).

8.2.1.3.1 Cloning existing volumes

Another way to add volumes to a pool is to clone an existing volume. The new instance is always created in the same pool as the original.

```
> virsh vol-clone NAME_EXISTING_VOLUME❶NAME_NEW_VOLUME❷ --pool POOL❸
```

❶ Name of the existing volume that should be cloned

❷ Name of the new volume

3 Optional parameter. `libvirt` tries to locate the existing volume automatically. If that fails, specify this parameter.

8.2.1.4 Deleting volumes from a storage pool

To permanently delete a volume from a pool, use the subcommand `vol-delete`:

```
> virsh vol-delete NAME --pool POOL
```

`--pool` is optional. `libvirt` tries to locate the volume automatically. If that fails, specify this parameter.

Warning: No checks upon volume deletion

A volume is deleted in any case, regardless of whether it is currently used in an active or inactive VM Guest. There is no way to recover a deleted volume.

Whether a volume is used by a VM Guest can only be detected by using by the method described in *Procedure 8.2, “Listing all storage volumes currently used on a VM Host Server”*.

8.2.1.5 Attaching volumes to a VM Guest

After you create a volume as described in *Section 8.2.1.3, “Adding volumes to a storage pool”*, you can attach it to a virtual machine and use it as a hard disk:

```
> virsh attach-disk DOMAIN SOURCE_IMAGE_FILE TARGET_DISK_DEVICE
```

For example:

```
> virsh attach-disk sles12sp3 /virt/images/example_disk.qcow2 sda2
```

To check if the new disk is attached, inspect the result of the **`virsh dumpxml`** command:

```
# virsh dumpxml sles12sp3
[...]
<disk type='file' device='disk'>
 <driver name='qemu' type='raw'/>
 <source file='/virt/images/example_disk.qcow2'/>
 <backingStore/>
 <target dev='sda2' bus='scsi'/>
 <alias name='scsi0-0-0'/>
 <address type='drive' controller='0' bus='0' target='0' unit='0'/>
</disk>
[...]
```

8.2.1.5.1 Hotplug or persistent change

You can attach disks to both active and inactive domains. The attachment is controlled by the `--live` and `--config` options:

`--live`
: Hotplugs the disk to an active domain. The attachment is not saved in the domain configuration. Using `--live` on an inactive domain is an error.

`--config`
: Changes the domain configuration persistently. The attached disk is then available after the next domain start.

`--live --config`
: Hotplugs the disk and adds it to the persistent domain configuration.

Tip: `virsh attach-device`

`virsh attach-device` is the more generic form of **`virsh attach-disk`**. You can use it to attach other types of devices to a domain.

8.2.1.6 Detaching volumes from a VM Guest

To detach a disk from a domain, use **`virsh detach-disk`**:

```
# virsh detach-disk DOMAIN TARGET_DISK_DEVICE
```

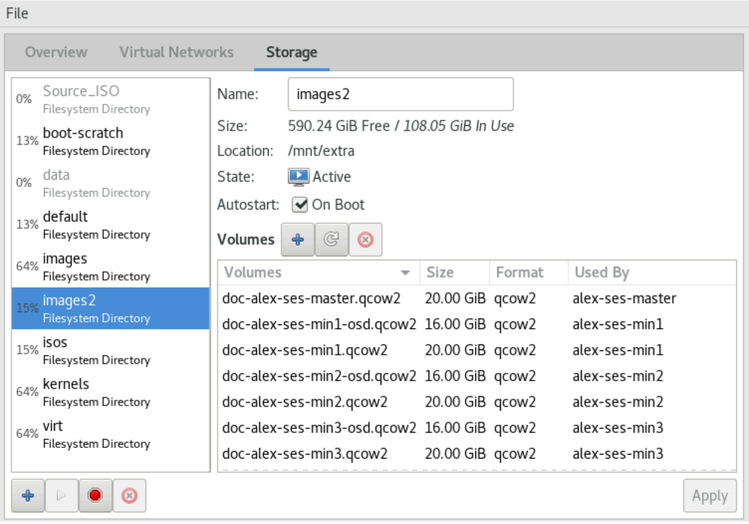
For example:

```
# virsh detach-disk sles12sp3 sda2
```

You can control the attachment with the `--live` and `--config` options as described in *Section 8.2.1.5, “Attaching volumes to a VM Guest”*.

8.2.2 Managing storage with Virtual Machine Manager

The Virtual Machine Manager provides a graphical interface—the Storage Manager—to manage storage volumes and pools. To access it, either right-click a connection and choose *Details*, or highlight a connection and choose *Edit* › *Connection Details*. Select the *Storage* tab.



0%	Source_ISO	Filesystem Directory
13%	boot-scratch	Filesystem Directory
0%	data	Filesystem Directory
13%	default	Filesystem Directory
64%	images	Filesystem Directory
15%	images2	Filesystem Directory
15%	isos	Filesystem Directory
64%	kernels	Filesystem Directory
64%	virt	Filesystem Directory

Name: images2

Size: 590.24 GiB Free / *108.05 GiB In Use*

Location: /mnt/extra

State: Active

Autostart: ☑ On Boot

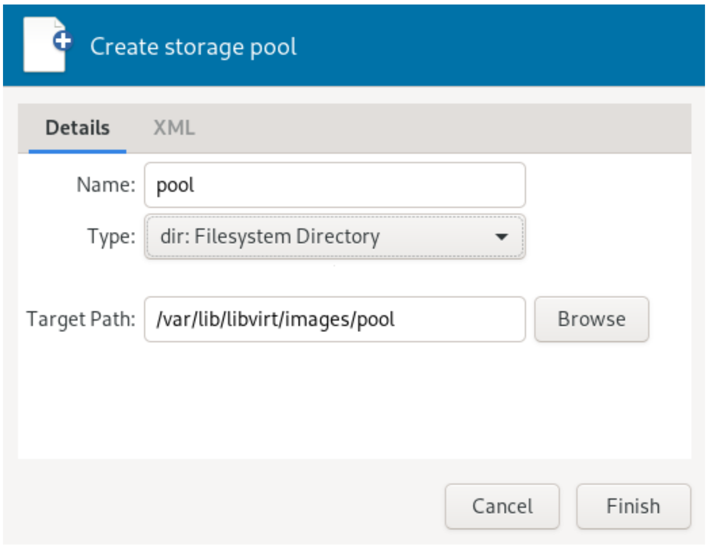
Volumes	Size	Format	Used By
doc-alex-ses-master.qcow2	20.00 GiB	qcow2	alex-ses-master
doc-alex-ses-min1-osd.qcow2	16.00 GiB	qcow2	alex-ses-min1
doc-alex-ses-min1.qcow2	20.00 GiB	qcow2	alex-ses-min1
doc-alex-ses-min2-osd.qcow2	16.00 GiB	qcow2	alex-ses-min2
doc-alex-ses-min2.qcow2	20.00 GiB	qcow2	alex-ses-min2
doc-alex-ses-min3-osd.qcow2	16.00 GiB	qcow2	alex-ses-min3
doc-alex-ses-min3.qcow2	20.00 GiB	qcow2	alex-ses-min3

8.2.2.1 Adding a storage pool

To add a storage pool, proceed as follows:

1. Click *Add* in the bottom left corner. The dialog *Add a New Storage Pool* appears.

2. Provide a *Name* for the pool (consisting of only alphanumeric characters and `_`, `-` or `.`) and select a *Type*.



Name: pool

Type: dir: Filesystem Directory

Target Path: /var/lib/libvirt/images/pool

3. Specify the required details below. They depend on the type of pool you are creating.

Important

ZFS pools are not supported.

Type *dir*

- *Target Path*: specify an existing directory.

Type *disk*

- *Format*: format of the device's partition table. Using *auto* should normally work. If not, get the required format by running the command **`parted`** `-l` on the VM Host Server.
- *Source Path*: path to the device. It is recommended to use a device name from `/dev/disk/by-*` rather than the simple `/dev/sdX`, since the latter can change (for example, when adding or removing hard disks). You need to specify the path that resembles the whole disk, not a partition on the disk (if existing).

Type *fs*

- *Target Path*: mount point on the VM Host Server file system.
- *Format:* file system format of the device. The default value `auto` should work.
- *Source Path*: path to the device file. It is recommended to use a device name from `/dev/disk/by-*` rather than `/dev/sdX`, because the latter can change (for example, when adding or removing hard disks).

Type *iscsi*

Get the necessary data by running the following command on the VM Host Server:

```
> sudo iscsiadm --mode node
```

It returns a list of iSCSI volumes with the following format. The elements in bold text are required:

```
IP_ADDRESS:PORT,TPGT TARGET_NAME_(IQN)
```

- *Target Path*: the directory containing the device file. Use `/dev/disk/by-path` (default) or `/dev/disk/by-id`.
- *Host Name*: host name or IP address of the iSCSI server.
- *Source IQN*: the iSCSI target name (iSCSI Qualified Name).
- *Initiator IQN*: the iSCSI initiator name.

Type *logical*

- *Volgroup Name*: specify the device path of an existing volume group.

Type *mpath*

- *Target Path*: support for multipathing is currently limited to making all multipath devices available. Therefore, specify an arbitrary string here. The path is required, otherwise the XML parser fails.

Type *netfs*

- *Target Path*: mount point on the VM Host Server file system.
- *Host Name*: IP address or host name of the server exporting the network file system.
- *Source Path*: directory on the server that is being exported.

Type *rbd*

- *Host Name*: host name of the server with an exported RADOS block device.
- *Source Name*: name of the RADOS block device on the server.

Type *scsi*

- *Target Path*: directory containing the device file. Use `/dev/disk/by-path` (default) or `/dev/disk/by-id`.
- *Source Path*: name of the SCSI adapter.

Note: File browsing

Using the file browser by clicking *Browse* is not possible when operating remotely.

4. Click *Finish* to add the storage pool.

8.2.2.2 Managing storage pools

Virtual Machine Manager's Storage Manager lets you create or delete volumes in a pool. You may also temporarily deactivate or permanently delete existing storage pools. Changing the basic configuration of a pool is currently not supported by SUSE.

8.2.2.2.1 Starting, stopping, and deleting pools

The purpose of storage pools is to provide block devices located on the VM Host Server that can be added to a VM Guest when managing it from remote. To make a pool temporarily inaccessible from remote, click *Stop* in the bottom left corner of the Storage Manager. Stopped pools are marked with *State: Inactive* and are grayed out in the list pane. By default, a newly created pool is automatically started *On Boot* of the VM Host Server.

To start an inactive pool and make it available from remote again, click *Start* in the bottom left corner of the Storage Manager.

> **Note: A pool's state does not affect attached volumes**
>
> Volumes from a pool attached to VM Guests are always available, regardless of the pool's state (*Active* (stopped) or *Inactive* (started)). The state of the pool solely affects the ability to attach volumes to a VM Guest via remote management.

To permanently make a pool inaccessible, click *Delete* in the bottom left corner of the Storage Manager. You can only delete inactive pools. Deleting a pool does not physically erase its contents on VM Host Server—it only deletes the pool configuration. However, you need to be extra careful when deleting pools, especially when deleting LVM volume group-based tools:

> **Warning: Deleting storage pools**
>
> Deleting storage pools based on *local* file system directories, local partitions or disks has no effect on the availability of volumes from these pools currently attached to VM Guests.
>
> Volumes located in pools of type iSCSI, SCSI, LVM group or Network Exported Directory become inaccessible from the VM Guest if the pool is deleted. Although the volumes themselves are not deleted, the VM Host Server can no longer access the resources.
>
> Volumes on iSCSI/SCSI targets or Network Exported Directory become accessible again when creating an adequate new pool or when mounting/accessing these resources directly from the host system.

When deleting an LVM group-based storage pool, the LVM group definition is erased and the LVM group no longer exists on the host system. The configuration is not recoverable and all volumes from this pool are lost.

8.2.2.2.2 Adding volumes to a storage pool

Virtual Machine Manager lets you create volumes in all storage pools, except in pools of types Multipath, iSCSI or SCSI. A volume in these pools is equivalent to a LUN and cannot be changed from within `libvirt`.

1. A new volume can either be created using the Storage Manager or while adding a new storage device to a VM Guest. In either case, select a storage pool from the left panel, then click *Create new volume*.

2. Specify a *Name* for the image and choose an image format.
   SUSE currently only supports `raw` or `qcow2` images. The latter option is not available on LVM group-based pools.
   Next to *Max Capacity*, specify the maximum size that the disk image is allowed to reach. Unless you are working with a `qcow2` image, you can also set an amount for *Allocation* that should be allocated initially. If the two values differ, a sparse image file is created, which grows on demand.
   For `qcow2` images, you can use a *Backing Store* (also called “backing file”), which constitutes a base image. The newly created `qcow2` image then only records the changes that are made to the base image.

3. Start the volume creation by clicking *Finish*.

8.2.2.2.3 Deleting volumes from a storage pool

Deleting a volume can only be done from the Storage Manager, by selecting a volume and clicking *Delete Volume*. Confirm with *Yes*.

Warning: Volumes can be deleted even while in use

Volumes can be deleted even if they are currently used in an active or inactive VM Guest. There is no way to recover a deleted volume.

Whether a volume is used by a VM Guest is indicated in the *Used By* column in the Storage Manager.

9 Guest installation

A VM Guest consists of an image containing an operating system and data files and a configuration file describing the VM Guest's virtual hardware resources. VM Guests are hosted on and controlled by the VM Host Server. This section provides generalized instructions for installing a VM Guest.

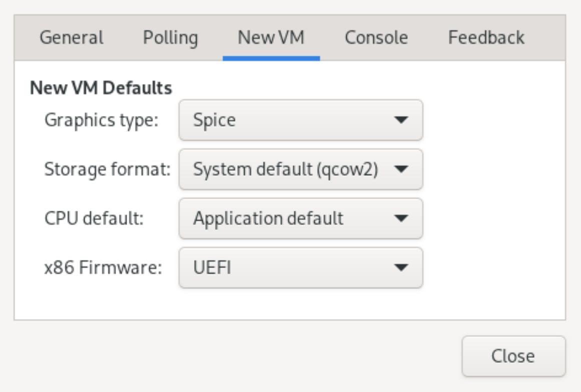
Virtual machines have few if any requirements above those required to run the operating system. If the operating system has not been optimized for the virtual machine host environment, it can only run on *hardware-assisted* virtualization computer hardware, in full virtualization mode, and requires specific device drivers to be loaded. The hardware that is presented to the VM Guest depends on the configuration of the host.

You should be aware of any licensing issues related to running a single licensed copy of an operating system on multiple virtual machines. Consult the operating system license agreement for more information.

9.1 GUI-based guest installation

Tip: Changing default options for new virtual machines

You can change default values that are applied when creating new virtual machines. For example, to set UEFI as the default firmware type for new virtual machines, select *Edit* › *Preferences* from Virtual Machine Manager's main menu, click *New VM* and set *UEFI* as the firmware default.



New VM Defaults

Graphics type: Spice

Storage format: System default (qcow2)

CPU default: Application default

x86 Firmware: UEFI

FIGURE 9.1: SPECIFYING DEFAULT OPTIONS FOR NEW VMS

The *New VM* wizard helps you through the steps required to create a virtual machine and install its operating system. To start it, open the Virtual Machine Manager and select *File* › *New Virtual Machine*. Alternatively, start YaST and select *Virtualization* › *Create Virtual Machines*.

1. Start the *New VM* wizard either from YaST or Virtual Machine Manager.

2. Choose an installation source—either a locally available media or a network installation source. To set up your VM Guest from an existing image, choose *import existing disk image*. On a VM Host Server running the Xen hypervisor, you can choose whether to install a paravirtualized or a fully virtualized guest. The respective option is available under *Architecture Options*. Depending on this choice, not all installation options may be available.

3. Depending on your choice in the previous step, you need to provide the following data:

   Local install media (ISO image or CDROM)

   Specify the path on the VM Host Server to an ISO image containing the installation data. If it is available as a volume in a libvirt storage pool, you can also select it using *Browse*. For more information, see *Chapter 12, Advanced storage topics*.
   Alternatively, choose a physical CD-ROM or DVD inserted in the optical drive of the VM Host Server.

   Network install (HTTP, HTTPS or FTP)

   Provide the *URL* pointing to the installation source. Valid URL prefixes are, for example, `ftp://`, `http://`, and `https://`.
   Under *URL Options*, provide a path to an auto-installation file (AutoYaST or Kickstart, for example) and kernel parameters. Having provided a URL, the operating system should be automatically detected correctly. If this is not the case, deselect *Automatically Detect Operating System Based on Install-Media* and manually select the *OS Type* and *Version*.

   Import existing disk image

   To set up the VM Guest from an existing image, you need to specify the path on the VM Host Server to the image. If it is available as a volume in a libvirt storage pool, you can also select it using *Browse*. For more information, see *Chapter 12, Advanced storage topics*.

Manual install

This installation method is suitable to create a virtual machine, manually configure its components, and install its OS later. To adjust the VM to a specific product version, start typing its name—for example, `sles`—and select the desired version when a match appears.

4. Choose the memory size and number of CPUs for the new virtual machine.

5. This step is omitted when *Import an Existing Image* is chosen in the first step.
Set up a virtual hard disk for the VM Guest. Either create a new disk image or choose an existing one from a storage pool (for more information, see *Chapter 12, Advanced storage topics*). If you choose to create a disk, a `qcow2` image is created and stored under `/var/lib/libvirt/images` by default.
Setting up a disk is optional. If you are running a live system directly from CD or DVD, for example, you can omit this step by deactivating *Enable Storage for this Virtual Machine*.

6. On the last screen of the wizard, specify the name for the virtual machine. To be offered the possibility to review and make changes to the virtualized hardware selection, activate *Customize configuration before install*. Specify the network device under *Network Selection*. When using *Bridge device*, the first bridge found on the host is pre-filled. To use a different bridge, manually update the text box with its name.
Click *Finish*.

7. *(Optional)* If you kept the defaults in the previous step, the installation starts. If you selected *Customize configuration before install*, a VM Guest configuration dialog opens. For more information about configuring VM Guests, see *Chapter 13, Configuring virtual machines with Virtual Machine Manager*.
When you are done configuring, click *Begin Installation*.

Tip: Passing key combinations to virtual machines

The installation starts in a Virtual Machine Manager console window. Some key combinations, such as `Ctrl`–`Alt`–`F1`, are recognized by the VM Host Server but are not passed to the virtual machine. To bypass the VM Host Server, Virtual Machine Manager provides the “sticky key” functionality. Pressing `Ctrl`, `Alt`, or `Shift` three times makes the key sticky, then you can press the remaining keys to pass the combination to the virtual machine.

For example, to pass `Ctrl` – `Alt` – `F2` to a Linux virtual machine, press `Ctrl` three times, then press `Alt` – `F2` . You can also press `Alt` three times, then press `Ctrl` – `F2` .

The sticky key functionality is available in the Virtual Machine Manager during and after installing a VM Guest.

9.1.1 Configuring the virtual machine for PXE boot

PXE boot enables your virtual machine to boot from the installation media via the network, instead of from a physical medium or an installation disk image.

To let your VM boot from a PXE server, follow these steps:

1. Start the installation wizard as described in *Section 9.1, "GUI-based guest installation"*.
2. Select the *Manual Install* method.
3. Proceed to the last step of the wizard and activate *Customize configuration before install*. Confirm with *Finish*.
4. On the *Customize* screen, select *Boot Options*.
5. Inspect *Boot device order* and activate the box next to *Enable boot menu*.
6. Under *Enable boot menu*, activate *Network PXE* and confirm with *Apply*.
7. Start the installation by clicking *Begin Installation*. If a PXE server is properly configured, the PXE menu screen appears.

9.2 Installing from the command line with `virt-install`

`virt-install` is a command-line tool that helps you create new virtual machines using the `libvirt` library. It is useful if you cannot use the graphical user interface, or need to automatize the process of creating virtual machines.

`virt-install` is a complex script with a lot of command line switches. The following are required. For more information, see the man page of **`virt-install`** (1).

General options

- `--name VM_GUEST_NAME`: Specify the name of the new virtual machine. The name must be unique across all guests known to the hypervisor on the same connection. It is used to create and name the guest's configuration file and you can access the guest with this name from **`virsh`**. Alphanumeric and `_-.:+` characters are allowed.

- `--memory REQUIRED_MEMORY`: Specify the amount of memory to allocate for the new virtual machine in megabytes.

- `--vcpus NUMBER_OF_CPUS`: Specify the number of virtual CPUs. For best performance, the number of virtual processors should be less than or equal to the number of physical processors.

Virtualization type

- `--paravirt`: set up a paravirtualized guest. This is the default if the VM Host Server supports paravirtualization and full virtualization.

- `--hvm`: set up a fully virtualized guest.

- `--virt-type HYPERVISOR`: Specify the hypervisor. Supported values are `kvm` or `xen`.

Guest storage

Specify one of `--disk`, `--filesystem` or `--nodisks` the type of the storage for the new virtual machine. For example, `--disk size=10` creates 10 GB disk in the default image location for the hypervisor and uses it for the VM Guest. `--filesystem /export/path/on/vmhost` specifies the directory on the VM Host Server to be exported to the guest. And `--nodisks` sets up a VM Guest without a local storage (good for Live CDs).

Installation method

Specify the installation method using one of `--location`, `--cdrom`, `--pxe`, `--import`, or `--boot` .

Accessing the installation

Use the `--graphics VALUE` option to specify how to access the installation. openSUSE Leap supports the values `vnc` or `none`.

If using VNC, **`virt-install`** tries to launch **`virt-viewer`**. If it is not installed or cannot be run, connect to the VM Guest manually with your preferred viewer. To explicitly prevent **`virt-install`** from launching the viewer, use `--noautoconsole`. To define a password for accessing the VNC session, use the following syntax: `--graphics vnc,password=`*`PASSWORD`*.

In case you are using `--graphics none`, you can access the VM Guest through operating system supported services, such as SSH or VNC. Refer to the operating system installation manual on how to set up these services in the installation system.

Passing kernel and initrd files

It is possible to directly specify the Kernel and Initrd of the installer, for example, from a network source.

To pass additional boot parameters, use the `--extra-args` option. This can be used to specify a network configuration. For details, see https://en.opensuse.org/SDB:Linuxrc ↗.

EXAMPLE 9.1: LOADING KERNEL AND INITRD FROM HTTP SERVER

```
# virt-install --location \
"http://download.opensuse.org/pub/opensuse/distribution/leap/15.0/repo/oss" \
--extra-args="textmode=1" --name "Leap15" --memory 2048 --virt-type kvm \
--connect qemu:///system --disk size=10 --graphics vnc --network \
network=vnet_nated
```

Enabling the console

By default, the console is not enabled for new virtual machines installed using **`virt-install`**. To enable it, use `--extra-args="console=ttyS0 textmode=1"` as in the following example:

```
> virt-install --virt-type kvm --name sles12 --memory 1024 \
 --disk /var/lib/libvirt/images/disk1.qcow2 --os-variant sles12
 --extra-args="console=ttyS0 textmode=1" --graphics none
```

After the installation finishes, the `/etc/default/grub` file in the VM image is updated with the `console=ttyS0` option on the `GRUB_CMDLINE_LINUX_DEFAULT` line.

Using UEFI Secure Boot

Install OVMF as described in *Section 6.3, “Installing UEFI support”*. Then add the `--boot uefi` option to the **`virt-install`** command.

UEFI Secure Boot is used automatically when setting up a new VM with OVMF. To use specific firmware, use `--boot loader=`*`PATH_TO_FIRMWARE`*.

For example, for the AArch64 architecture:

```
--boot loader=/usr/share/qemu/qemu-uefi-aarch32.bin
```

And for the AMD64/Intel 64; architecture:

```
--boot loader=/usr/share/qemu/ovmf-x86_64-opensuse.bin
```

EXAMPLE 9.2: EXAMPLE OF A `virt-install` COMMAND LINE

> The following command line example creates a new SUSE Linux Enterprise 15 SP2 virtual machine with a virtio accelerated disk and network card. It creates a new 10 GB qcow2 disk image as a storage, the source installation media being the host CD-ROM drive. It uses VNC graphics, and it automatically launches the graphical client.
>
> KVM
>
> ```
> > virt-install --connect qemu:///system --virt-type kvm \
> --name sle15sp2 --memory 1024 --disk size=10 --cdrom /dev/cdrom --graphics vnc
>  \
> --os-variant sle15sp2
> ```
>
> Xen
>
> ```
> > virt-install --connect xen:// --virt-type xen --hvm \
> --name sle15sp2 --memory 1024 --disk size=10 --cdrom /dev/cdrom --graphics vnc
>  \
> --os-variant sle15sp2
> ```

9.3 Advanced guest installation scenarios

This section provides instructions for operations exceeding the scope of a normal installation, such as memory ballooning and installing add-on products.

9.3.1 Including add-on products in the installation

Some operating systems, such as openSUSE Leap, offer to include add-on products in the installation process. If the add-on product installation source is provided via SUSE Customer Center, no special VM Guest configuration is needed. If it is provided via CD/DVD or ISO image, it is necessary to provide the VM Guest installation system with both the standard installation medium image and the image of the add-on product.

If you are using the GUI-based installation, select *Customize Configuration Before Install* in the last step of the wizard and add the add-on product ISO image via *Add Hardware* › *Storage*. Specify the path to the image and set the *Device Type* to *CD-ROM*.

If you are installing from the command line, you need to set up the virtual CD/DVD drives with the `--disk` parameter rather than with `--cdrom`. The device that is specified first is used for booting. The following example installs SUSE Linux Enterprise Server 15 together with SUSE Enterprise Storage extension:

```
> virt-install \
 --name sles15+storage \
 --memory 2048 --disk size=10 \
 --disk /path/to/SLE-15-SP5-Full-ARCH-GM-media1.iso-x86_64-GM-DVD1.iso,device=cdrom \
 --disk /path/to/SUSE-Enterprise-Storage-VERSION-DVD-ARCH-Media1.iso,device=cdrom \
 --graphics vnc --os-variant sle15
```

10 Basic VM Guest management

Most management tasks, such as starting or stopping a VM Guest, can either be done using the graphical application Virtual Machine Manager or on the command line using `virsh`. Connecting to the graphical console via VNC is only possible from a graphical user interface.

Note: Managing VM Guests on a remote VM Host Server

If started on a VM Host Server, the `libvirt` tools Virtual Machine Manager, `virsh`, and `virt-viewer` can be used to manage VM Guests on the host. However, it is also possible to manage VM Guests on a remote VM Host Server. This requires configuring remote access for `libvirt` on the host. For instructions, see *Chapter 11, Connecting and authorizing*.

To connect to such a remote host with Virtual Machine Manager, you need to set up a connection as explained in *Section 11.2.2, "Managing connections with Virtual Machine Manager"*. If connecting to a remote host using `virsh` or `virt-viewer`, you need to specify a connection URI with the parameter `-c` (for example, `virsh -c qemu+tls://saturn.example.com/system` or `virsh -c xen+ssh://`). The form of connection URI depends on the connection type and the hypervisor—see *Section 11.2, "Connecting to a VM Host Server"* for details.

Examples in this chapter are all listed without a connection URI.

10.1 Listing VM Guests

The VM Guest listing shows all VM Guests managed by `libvirt` on a VM Host Server.

10.1.1 Listing VM Guests with Virtual Machine Manager

The main window of the Virtual Machine Manager lists all VM Guests for each VM Host Server it is connected to. Each VM Guest entry contains the machine's name, its status (*Running*, *Paused*, or *Shutoff*) displayed as an icon and literally, and a CPU usage bar.

10.1.2 Listing VM Guests with **virsh**

Use the command **virsh** list to get a list of VM Guests:

List all running guests

```
> virsh list
```

List all running and inactive guests

```
> virsh list --all
```

For more information and further options, see **virsh help list** or **man 1 virsh**.

10.2 Accessing the VM Guest via console

VM Guests can be accessed via a VNC connection (graphical console) or, if supported by the guest operating system, via a serial console.

10.2.1 Opening a graphical console

Opening a graphical console to a VM Guest lets you interact with the machine like a physical host via a VNC connection. If accessing the VNC server requires authentication, you are prompted to enter a user name (if applicable) and a password.

When you click into the VNC console, the cursor is “grabbed” and cannot be used outside the console anymore. To release it, press **Alt**–**Ctrl**.

Tip: Seamless (absolute) cursor movement

To prevent the console from grabbing the cursor and to enable seamless cursor movement, add a tablet input device to the VM Guest. See *Section 13.5, “Input devices”* for more information.

Certain key combinations such as **Ctrl**–**Alt**–**Del** are interpreted by the host system and are not passed to the VM Guest. To pass such key combinations to a VM Guest, open the *Send Key* menu from the VNC window and choose the desired key combination entry. The *Send Key* menu is only available when using Virtual Machine Manager and **virt-viewer**. With Virtual Machine Manager, you can alternatively use the “sticky key” feature as explained in *Tip: Passing key combinations to virtual machines*.

Note: Supported VNC viewers

Principally all VNC viewers can connect to the console of a VM Guest. However, if you are using SASL authentication and/or TLS/SSL connection to access the guest, the options are limited. Common VNC viewers such as **tightvnc** or **tigervnc** support neither SASL authentication nor TLS/SSL. The only supported alternative to Virtual Machine Manager and **virt-viewer** is Remmina (refer to *Book “Reference”, Chapter 4 “Remote graphical sessions with VNC”, Section 4.2 “Remmina: the remote desktop client”*).

10.2.1.1 Opening a graphical console with Virtual Machine Manager

1. In the Virtual Machine Manager, right-click a VM Guest entry.
2. Choose *Open* from the pop-up menu.

10.2.1.2 Opening a graphical console with **virt-viewer**

virt-viewer is a simple VNC viewer with added functionality for displaying VM Guest consoles. For example, it can be started in “wait” mode, where it waits for a VM Guest to start before it connects. It also supports automatically reconnecting to a VM Guest that is rebooted.

virt-viewer addresses VM Guests by name, by ID or by UUID. Use **virsh** `list --all` to get this data.

To connect to a guest that is running or paused, use either the ID, UUID or name. VM Guests that are shut off do not have an ID—you can only connect to them by UUID or name.

Connect to guest with the ID `8`

```
> virt-viewer 8
```

Connect to the inactive guest named `sles12`; the connection window opens once the guest starts

```
> virt-viewer --wait sles12
```

With the `--wait` option, the connection is upheld even if the VM Guest is not running at the moment. When the guest starts, the viewer is launched.

For more information, see **`virt-viewer`** `--help` or **`man 1 virt-viewer`**.

Note: Password input on remote connections with SSH

When using **`virt-viewer`** to open a connection to a remote host via SSH, the SSH password needs to be entered twice. The first time for authenticating with `libvirt`, the second time for authenticating with the VNC server. The second password needs to be provided on the command line where virt-viewer was started.

10.2.2 Opening a serial console

Accessing the graphical console of a virtual machine requires a graphical environment on the client accessing the VM Guest. As an alternative, virtual machines managed with libvirt can also be accessed from the shell via the serial console and **`virsh`**. To open a serial console to a VM Guest named “sles12”, run the following command:

```
> virsh console sles12
```

`virsh console` takes two optional flags: `--safe` ensures exclusive access to the console, `--force` disconnects any existing sessions before connecting. Both features need to be supported by the guest operating system.

Being able to connect to a VM Guest via serial console requires that the guest operating system supports serial console access and is properly supported. Refer to the guest operating system manual for more information.

Tip: Enabling serial console access for SUSE Linux Enterprise and openSUSE guests

Serial console access in SUSE Linux Enterprise and openSUSE is disabled by default. To enable it, proceed as follows:

SLES 12, 15 and openSUSE

Launch the YaST Boot Loader module and switch to the *Kernel Parameters* tab. Add `console=ttyS0` to the field *Optional Kernel Command Line Parameter*.

SLES 11

Launch the YaST Boot Loader module and select the boot entry for which to activate serial console access. Choose *Edit* and add `console=ttyS0` to the field *Optional Kernel Command Line Parameter*. Additionally, edit `/etc/inittab` and uncomment the line with the following content:

```
#S0:12345:respawn:/sbin/agetty -L 9600 ttyS0 vt102
```

10.3 Changing a VM Guest's state: start, stop, pause

Starting, stopping or pausing a VM Guest can be done with either Virtual Machine Manager or **`virsh`**. You can also configure a VM Guest to be automatically started when booting the VM Host Server.

When shutting down a VM Guest, you may either shut it down gracefully, or force the shutdown. The latter is equivalent to pulling the power plug on a physical host and is only recommended if there are no alternatives. Forcing a shutdown may cause file system corruption and loss of data on the VM Guest.

Tip: Graceful shutdown

To be able to perform a graceful shutdown, the VM Guest must be configured to support *ACPI*. If you have created the guest with the Virtual Machine Manager, ACPI should be available in the VM Guest.

Depending on the guest operating system, availability of ACPI may not be sufficient to perform a graceful shutdown. It is strongly recommended to test shutting down and rebooting a guest before using it in production. openSUSE or SUSE Linux Enterprise Desktop, for example, can require Polkit authorization for shutdown and reboot. Make sure this policy is turned off on all VM Guests.

If ACPI was enabled during a Windows XP/Windows Server 2003 guest installation, turning it on in the VM Guest configuration only is not sufficient. For more information, see:

- https://support.microsoft.com/en-us/kb/314088
- https://support.microsoft.com/en-us/kb/309283

Regardless of the VM Guest's configuration, a graceful shutdown is always possible from within the guest operating system.

10.3.1 Changing a VM Guest's state with Virtual Machine Manager

Changing a VM Guest's state can be done either from Virtual Machine Manager's main window, or from a VNC window.

PROCEDURE 10.1: STATE CHANGE FROM THE VIRTUAL MACHINE MANAGER WINDOW

1. Right-click a VM Guest entry.
2. Choose *Run*, *Pause*, or one of the *Shutdown options* from the pop-up menu.

PROCEDURE 10.2: STATE CHANGE FROM THE VNC WINDOW

1. Open a VNC Window as described in *Section 10.2.1.1, "Opening a graphical console with Virtual Machine Manager"*.
2. Choose *Run*, *Pause*, or one of the *Shut Down* options either from the toolbar or from the *Virtual Machine* menu.

10.3.1.1 Automatically starting a VM Guest

You can automatically start a guest when the VM Host Server boots. This feature is not enabled by default and needs to be enabled for each VM Guest individually. There is no way to activate it globally.

1. Double-click the VM Guest entry in Virtual Machine Manager to open its console.
2. Choose *View* › *Details* to open the VM Guest configuration window.
3. Choose *Boot Options* and check *Start virtual machine on host boot up*.
4. Save the new configuration with *Apply*.

10.3.2 Changing a VM Guest's state with `virsh`

In the following examples, the state of a VM Guest named "sles12" is changed.

Start

```
> virsh start sles12
```

Pause

```
> virsh suspend sles12
```

Resume (a suspended VM Guest)

```
> virsh resume sles12
```

Reboot

```
> virsh reboot sles12
```

Graceful shutdown

```
> virsh shutdown sles12
```

Force shutdown

```
> virsh destroy sles12
```

Turn on automatic start

```
> virsh autostart sles12
```

Turn off automatic start

```
> virsh autostart --disable sles12
```

10.4 Saving and restoring the state of a VM Guest

Saving a VM Guest preserves the exact state of the guest’s memory. The operation is similar to *hibernating* a computer. A saved VM Guest can be quickly restored to its previously saved running condition.

When saved, the VM Guest is paused, its current memory state is saved to disk, and then the guest is stopped. The operation does not make a copy of any portion of the VM Guest’s virtual disk. The amount of time taken to save the virtual machine depends on the amount of memory allocated. When saved, a VM Guest’s memory is returned to the pool of memory available on the VM Host Server.

The restore operation loads a VM Guest’s previously saved memory state file and starts it. The guest is not booted but instead resumed at the point where it was previously saved. The operation is similar to coming out of hibernation.

The VM Guest is saved to a state file. Make sure there is enough space on the partition you are going to save to. For an estimation of the file size in megabytes to be expected, issue the following command on the guest:

```
> free -mh | awk '/^Mem:/ {print $3}'
```

Warning: Always restore saved guests

After using the save operation, do not boot or start the saved VM Guest. Doing so would cause the machine's virtual disk and the saved memory state to get out of synchronization. This can result in critical errors when restoring the guest.

To be able to work with a saved VM Guest again, use the restore operation. If you used **`virsh`** to save a VM Guest, you cannot restore it using Virtual Machine Manager. In this case, make sure to restore using **`virsh`**.

Important: Synchronize VM Guest's time after restoring it

If you restore the VM Guest after a long pause (hours) since it was saved, its time synchronization service—for example, `chronyd`—may refuse to synchronize its time. In this case, manually synchronize VM Guest's time. For example, for KVM hosts, you can use the QEMU guest agent and instruct the guest with the **`guest-set-time`**. Refer to *Chapter 19, QEMU guest agent* for more details.

Important: Only for VM Guests with disk types `raw`, `qcow2`

Saving and restoring VM Guests is only possible if the VM Guest is using a virtual disk of the type `raw` (`.img`), or *qcow2*.

10.4.1 Saving/restoring with Virtual Machine Manager

PROCEDURE 10.3: SAVING A VM GUEST

1. Open a VNC connection window to a VM Guest. Make sure the guest is running.

2. Choose *Virtual Machine* › *Shutdown* › *Save*.

PROCEDURE 10.4: RESTORING A VM GUEST

1. Open a VNC connection window to a VM Guest. Make sure the guest is not running.

2. Choose *Virtual Machine* › *Restore*.
   If the VM Guest was previously saved using Virtual Machine Manager, you are not offered an option to *Run* the guest. However, note the caveats on machines saved with **`virsh`** outlined in *Warning: Always restore saved guests*.

10.4.2 Saving and restoring with **virsh**

Save a running VM Guest with the command **`virsh`** `save` and specify the file which it is saved to.

Save the guest named `opensuse13`

```
> virsh save opensuse13 /virtual/saves/opensuse13.vmsav
```

Save the guest with the ID `37`

```
> virsh save 37 /virtual/saves/opensuse13.vmsave
```

To restore a VM Guest, use **`virsh`** `restore`:

```
> virsh restore /virtual/saves/opensuse13.vmsave
```

10.5 Creating and managing snapshots

VM Guest snapshots are snapshots of the complete virtual machine including the state of CPU, RAM, devices and the content of all writable disks. To use virtual machine snapshots, all the attached hard disks need to use the qcow2 disk image format, and at least one of them needs to be writable.

Snapshots let you restore the state of the machine at a particular point in time. This is useful when undoing a faulty configuration or the installation of a lot of packages. After starting a snapshot that was created while the VM Guest was shut off, you need to boot it. Any changes written to the disk afterward are lost when starting the snapshot.

Note

Snapshots are supported on KVM VM Host Servers only.

10.5.1 Terminology

There are several specific terms used to describe the types of snapshots:

Internal snapshots

Snapshots that are saved into the qcow2 file of the original VM Guest. The file holds both the saved state of the snapshot and the changes made since the snapshot was taken. The main advantage of internal snapshots is that they are all stored in one file and therefore it is easy to copy or move them across multiple machines.

External snapshots

When creating an external snapshot, the original qcow2 file is saved and made read-only, while a new qcow2 file is created to hold the changes. The original file is sometimes called a *backing* or *base* file, while the new file with all the changes is called an *overlay* or *derived* file. External snapshots are useful when performing backups of VM Guests. However, external snapshots are not supported by Virtual Machine Manager, and cannot be deleted by `virsh` directly. For more information on external snapshots in QEMU, refer to *Section 33.2.4, "Manipulate disk images effectively"*.

Live snapshots

Snapshots created when the original VM Guest is running. Internal live snapshots support saving the devices, and memory and disk states, while external live snapshots with `virsh` support saving either the memory state, or the disk state, or both.

Offline snapshots

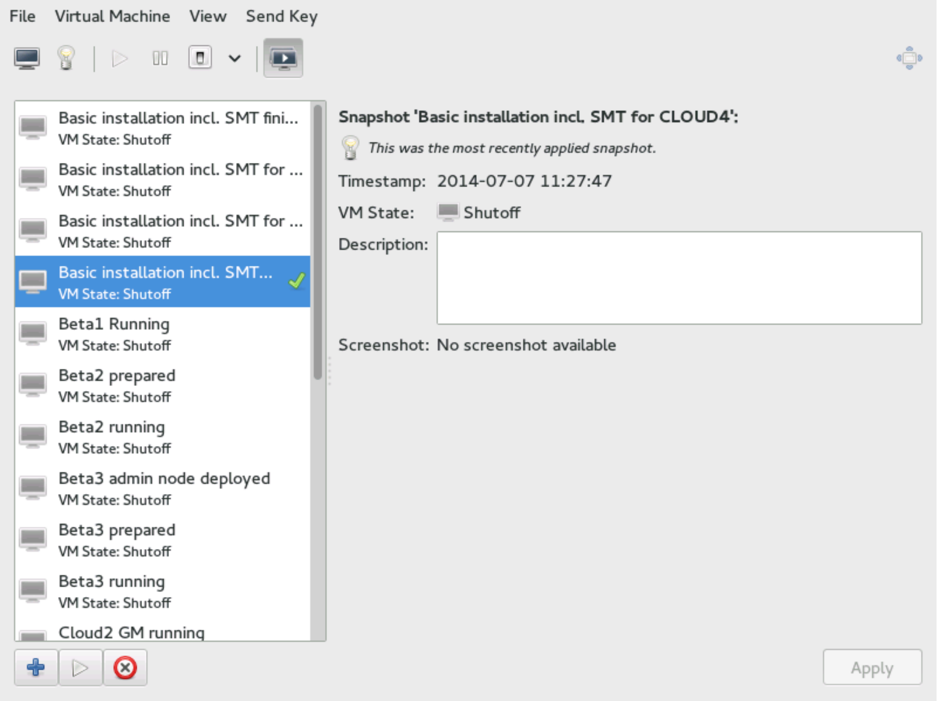
Snapshots created from a VM Guest that is shut off. This ensures data integrity as all the guest's processes are stopped and no memory is in use.

10.5.2 Creating and managing snapshots with Virtual Machine Manager

Important: Internal snapshots only

Virtual Machine Manager supports only internal snapshots, either live or offline.

To open the snapshot management view in Virtual Machine Manager, open the VNC window as described in *Section 10.2.1.1, "Opening a graphical console with Virtual Machine Manager"*. Now either choose *View* › *Snapshots* or click *Manage VM Snapshots* in the toolbar.



Basic installation incl. SMT fini...
VM State: Shutoff

Basic installation incl. SMT for ...
VM State: Shutoff

Basic installation incl. SMT for ...
VM State: Shutoff

Basic installation incl. SMT... ✓
VM State: Shutoff

Beta1 Running
VM State: Shutoff

Beta2 prepared
VM State: Shutoff

Beta2 running
VM State: Shutoff

Beta3 admin node deployed
VM State: Shutoff

Beta3 prepared
VM State: Shutoff

Beta3 running
VM State: Shutoff

Cloud2 GM running

Snapshot 'Basic installation incl. SMT for CLOUD4':

This was the most recently applied snapshot.

Timestamp: 2014-07-07 11:27:47

VM State: Shutoff

Description:

Screenshot: No screenshot available

The list of existing snapshots for the chosen VM Guest is displayed in the left-hand part of the window. The snapshot that was last started is marked with a green tick. The right-hand part of the window shows details of the snapshot currently marked in the list. These details include the snapshot's title and time stamp, the state of the VM Guest at the time the snapshot was taken and a description. Snapshots of running guests also include a screenshot. The *Description* can be changed directly from this view. Other snapshot data cannot be changed.

10.5.2.1 Creating a snapshot

To take a new snapshot of a VM Guest, proceed as follows:

1. Optionally, shut down the VM Guest to create an offline snapshot.
2. Click *Add* in the bottom left corner of the VNC window.
   The window *Create Snapshot* opens.
3. Provide a *Name* and, optionally, a description. The name cannot be changed after the snapshot has been taken. To be able to identify the snapshot later easily, use a “speaking name”.
4. Confirm with *Finish*.

10.5.2.2 Deleting a snapshot

To delete a snapshot of a VM Guest, proceed as follows:

1. Click *Delete* in the bottom left corner of the VNC window.
2. Confirm the deletion with *Yes*.

10.5.2.3 Starting a snapshot

To start a snapshot, proceed as follows:

1. Click *Run* in the bottom left corner of the VNC window.
2. Confirm the start with *Yes*.

10.5.3 Creating and managing snapshots with **`virsh`**

To list all existing snapshots for a domain (`admin_server` in the following), run the `snapshot-list` command:

```
> virsh snapshot-list --domain sle-ha-node1
 Name                 Creation Time             State
------------------------------------------------------------
 sleha_12_sp2_b2_two_node_cluster 2016-06-06 15:04:31 +0200 shutoff
 sleha_12_sp2_b3_two_node_cluster 2016-07-04 14:01:41 +0200 shutoff
 sleha_12_sp2_b4_two_node_cluster 2016-07-14 10:44:51 +0200 shutoff
 sleha_12_sp2_rc3_two_node_cluster 2016-10-10 09:40:12 +0200 shutoff
 sleha_12_sp2_gmc_two_node_cluster 2016-10-24 17:00:14 +0200 shutoff
 sleha_12_sp3_gm_two_node_cluster 2017-08-02 12:19:37 +0200 shutoff
 sleha_12_sp3_rc1_two_node_cluster 2017-06-13 13:34:19 +0200 shutoff
 sleha_12_sp3_rc2_two_node_cluster 2017-06-30 11:51:24 +0200 shutoff
 sleha_15_b6_two_node_cluster 2018-02-07 15:08:09 +0100 shutoff
 sleha_15_rc1_one-node 2018-03-09 16:32:38 +0100 shutoff
```

The snapshot that was last started is shown with the `snapshot-current command:`

```
> virsh snapshot-current --domain admin_server
Basic installation incl. SMT for CLOUD4
```

Details about a particular snapshot can be obtained by running the `snapshot-info` command:

```
> virsh snapshot-info --domain admin_server \
   -name  "Basic installation incl. SMT for CLOUD4"
Name:           Basic installation incl. SMT for CLOUD4
Domain:         admin_server
Current:        yes
State:          shutoff
Location:       internal
Parent:         Basic installation incl. SMT for CLOUD3-HA
Children:       0
Descendants:    0
Metadata:       yes
```

10.5.3.1 Creating internal snapshots

To take an internal snapshot of a VM Guest, either a live or offline, use the `snapshot-create-as` command as follows:

```
> virsh snapshot-create-as --domain admin_server❶ --name "Snapshot 1"❷ \
--description "First snapshot"❸
```

❶ Domain name. Mandatory.

❷ Name of the snapshot. It is recommended to use a “speaking name”, since that makes it easier to identify the snapshot. Mandatory.

❸ Description for the snapshot. Optional.

10.5.3.2 Creating external snapshots

With **`virsh`**, you can take external snapshots of the guest's memory state, disk state, or both.

To take both live and offline external snapshots of the guest's disk, specify the `--disk-only` option:

```
> virsh snapshot-create-as --domain admin_server --name \
 "Offline external snapshot" --disk-only
```

You can specify the `--diskspec` option to control how the external files are created:

```
> virsh snapshot-create-as --domain admin_server --name \
 "Offline external snapshot" \
 --disk-only --diskspec vda,snapshot=external,file=/path/to/snapshot_file
```

To take a live external snapshot of the guest's memory, specify the `--live` and `--memspec` options:

```
> virsh snapshot-create-as --domain admin_server --name \
 "Offline external snapshot" --live \
 --memspec snapshot=external,file=/path/to/snapshot_file
```

To take a live external snapshot of both the guest's disk and memory states, combine the `--live`, `--diskspec`, and `--memspec` options:

```
> virsh snapshot-create-as --domain admin_server --name \
 "Offline external snapshot" --live \
 --memspec snapshot=external,file=/path/to/snapshot_file
 --diskspec vda,snapshot=external,file=/path/to/snapshot_file
```

Refer to the *SNAPSHOT COMMANDS* section in **`man 1 virsh`** for more details.

10.5.3.3 Deleting a snapshot

External snapshots cannot be deleted with **`virsh`**. To delete an internal snapshot of a VM Guest and restore the disk space it occupies, use the `snapshot-delete` command:

```
> virsh snapshot-delete --domain admin_server --snapshotname "Snapshot 2"
```

10.5.3.4 Starting a snapshot

To start a snapshot, use the `snapshot-revert` command:

```
> virsh snapshot-revert --domain admin_server --snapshotname "Snapshot 1"
```

To start the current snapshot (the one the VM Guest was started off), it is sufficient to use `--current` rather than specifying the snapshot name:

```
> virsh snapshot-revert --domain admin_server --current
```

10.6 Deleting a VM Guest

By default, deleting a VM Guest using **`virsh`** removes only its XML configuration. Since attached storage is not deleted by default, you can reuse it with another VM Guest. With Virtual Machine Manager, you can also delete a guest's storage files as well.

10.6.1 Deleting a VM Guest with Virtual Machine Manager

1. In the Virtual Machine Manager, right-click a VM Guest entry.

2. From the context menu, choose *Delete*.

3. A confirmation window opens. Clicking *Delete* permanently erases the VM Guest. The deletion is not recoverable.
   You can also permanently delete the guest's virtual disk by activating *Delete Associated Storage Files*. The deletion is not recoverable either.

10.6.2 Deleting a VM Guest with **virsh**

To delete a VM Guest, it needs to be shut down first. It is not possible to delete a running guest. For information on shutting down, see *Section 10.3, “Changing a VM Guest's state: start, stop, pause”*.

To delete a VM Guest with **`virsh`**, run **`virsh`** `undefine` *`VM_NAME`*.

```
> virsh undefine sles12
```

There is no option to automatically delete the attached storage files. If they are managed by libvirt, delete them as described in *Section 8.2.1.4, “Deleting volumes from a storage pool”*.

10.7 Migrating VM Guests

One of the major advantages of virtualization is that VM Guests are portable. When a VM Host Server needs to go down for maintenance, or when the host gets overloaded, the guests can easily be moved to another VM Host Server. KVM and Xen even support “live” migrations during which the VM Guest is constantly available.

10.7.1 Migration requirements

To successfully migrate a VM Guest to another VM Host Server, the following requirements need to be met:

Important

To use the post-copy live migration option, KVM hosts with kernel version 5.11 or newer require setting the `unprivileged_userfaultfd` system value to `1`:

```
> sudo sysctl -w vm.unprivileged_userfaultfd=1
```

Since kernel versions before 5.11 did not require setting unprivileged_userfaultfd to use the post-copy option, `libvirt` provides the setting in `/usr/lib/sysctl.d/60-qemu-postcopy-migration.conf` file to preserve the old behavior.

- The source and destination systems must have the same architecture.
- Storage devices must be accessible from both machines (for example, via NFS or iSCSI) and must be configured as a storage pool on both machines. For more information, see *Chapter 12, Advanced storage topics*.
  This is also true for CD-ROM or floppy images that are connected during the move. However, you can disconnect them before the move as described in *Section 13.11, “Ejecting and changing floppy or CD/DVD-ROM media with Virtual Machine Manager”*.
- `libvirtd` needs to run on both VM Host Servers and you must be able to open a remote `libvirt` connection between the target and the source host (or vice versa). Refer to *Section 11.3, “Configuring remote connections”* for details.

- If a firewall is running on the target host, ports need to be opened to allow the migration. If you do not specify a port during the migration process, `libvirt` chooses one from the range 49152:49215. Make sure that either this range (recommended) or a dedicated port of your choice is opened in the firewall on the *target host*.
- Host and target machine should be in the same subnet on the network, otherwise networking fails after the migration.
- All VM Host Servers participating in migration must have the same UID for the qemu user and the same GIDs for the kvm, qemu, and libvirt groups.
- No running or paused VM Guest with the same name must exist on the target host. If a shut down machine with the same name exists, its configuration is overwritten.
- All CPU models except *host cpu* model are supported when migrating VM Guests.
- *SATA* disk device type is not migratable.
- File system pass-through feature is incompatible with migration.
- The VM Host Server and VM Guest need to have proper timekeeping installed. See *Chapter 17, VM Guest clock settings*.
- No physical devices can be passed from host to guest. Live migration is currently not supported when using devices with PCI pass-through or *SR-IOV*. If live migration needs to be supported, you need to use software virtualization (paravirtualization or full virtualization).
- Cache mode setting is an important setting for migration. See: *Section 16.6, "Cache modes and live migration"*.
- The image directory should be located in the same path on both hosts.
- All hosts should be on the same level of microcode (especially the spectre microcode updates). This can be achieved by installing the latest updates of openSUSE Leap on all hosts.

10.7.2 Migrating with Virtual Machine Manager

When using the Virtual Machine Manager to migrate VM Guests, it does not matter on which machine it is started. You can start Virtual Machine Manager on the source or the target host or even on a third host. In the latter case you need to be able to open remote connections to both the target and the source host.

1. Start Virtual Machine Manager and establish a connection to the target or the source host. If the Virtual Machine Manager was started neither on the target nor the source host, connections to both hosts need to be opened.

2. Right-click the VM Guest that you want to migrate and choose *Migrate*. Make sure the guest is running or paused—it is not possible to migrate guests that are shut down.

   ### Tip: Increasing the speed of the migration

   To increase the speed of the migration, pause the VM Guest. This is the equivalent of the former so-called “offline migration” option of Virtual Machine Manager.

3. Choose a *New Host* for the VM Guest. If the desired target host does not show up, make sure that you are connected to the host.
   To change the default options for connecting to the remote host, under *Connection*, set the *Mode*, and the target host's *Address* (IP address or host name) and *Port*. If you specify a *Port*, you must also specify an *Address*.
   Under *Advanced options*, choose whether the move should be permanent (default) or temporary, using *Temporary move*.
   Additionally, there is the option *Allow unsafe*, which allows migrating without disabling the cache of the VM Host Server. This can speed up the migration but only works when the current configuration allows for a consistent view of the VM Guest storage without using `cache="none"`/`0_DIRECT`.

   ### Note: Bandwidth option

   In recent versions of Virtual Machine Manager, the option of setting a bandwidth for the migration has been removed. To set a specific bandwidth, use **`virsh`** instead.

4. To perform the migration, click *Migrate*.
   When the migration is complete, the *Migrate* window closes and the VM Guest is now listed on the new host in the Virtual Machine Manager window. The original VM Guest is still available on the target host (in shut down state).

10.7.3 Migrating with **virsh**

To migrate a VM Guest with **virsh** migrate, you need to have direct or remote shell access to the VM Host Server, because the command needs to be run on the host. The migration command looks like this:

```
> virsh migrate [OPTIONS] VM_ID_or_NAME CONNECTION_URI [--migrateuri
 tcp://REMOTE_HOST:PORT]
```

The most important options are listed below. See **virsh help migrate** for a full list.

`--live`

Does a live migration. If not specified, the guest is paused during the migration ("offline migration").

`--suspend`

Does an offline migration and does not restart the VM Guest on the target host.

`--persistent`

By default a migrated VM Guest is migrated temporarily, so its configuration is automatically deleted on the target host if it is shut down. Use this switch to make the migration persistent.

`--undefinesource`

When specified, the VM Guest definition on the source host is deleted after a successful migration (however, virtual disks attached to this guest are *not* deleted).

`--parallel --parallel-connections NUM_OF_CONNECTIONS`

Parallel migration can be used to increase migration data throughput in cases where a single migration thread is not capable of saturating the network link between source and destination hosts. On hosts with 40 GB network interfaces, it may require four migration threads to saturate the link. With parallel migration, the time required to migrate large memory VMs can be significantly reduced.

The following examples use mercury.example.com as the source system and jupiter.example.com as the target system; the VM Guest's name is `opensuse131` with Id `37`.

Offline migration with default parameters

```
> virsh migrate 37 qemu+ssh://tux@jupiter.example.com/system
```

Transient live migration with default parameters

```
> virsh migrate --live opensuse131 qemu+ssh://tux@jupiter.example.com/system
```

Persistent live migration; delete VM definition on source

```
> virsh migrate --live --persistent --undefinesource 37 \
qemu+tls://tux@jupiter.example.com/system
```

Offline migration using port 49152

```
> virsh migrate opensuse131 qemu+ssh://tux@jupiter.example.com/system \
--migrateuri tcp://@jupiter.example.com:49152
```

Note: Transient compared to persistent migrations

By default **`virsh migrate`** creates a temporary (transient) copy of the VM Guest on the target host. A shut down version of the original guest description remains on the source host. A transient copy is deleted from the server after it is shut down.

To create a permanent copy of a guest on the target host, use the switch `--persistent`. A shut down version of the original guest description remains on the source host, too. Use the option `--undefinesource` together with `--persistent` for a “real” move where a permanent copy is created on the target host and the version on the source host is deleted.

It is not recommended to use `--undefinesource` without the `--persistent` option, since this results in the loss of both VM Guest definitions when the guest is shut down on the target host.

10.7.4 Step-by-step example

10.7.4.1 Exporting the storage

First you need to export the storage, to share the Guest image between host. This can be done by an NFS server. In the following example we want to share the `/volume1/VM` directory for all machines that are on the network 10.0.1.0/24. We are using a SUSE Linux Enterprise NFS server. As root user, edit the `/etc/exports` file and add:

```
/volume1/VM 10.0.1.0/24  (rw,sync,no_root_squash)
```

You need to restart the NFS server:

```
> sudo systemctl restart nfsserver
> sudo exportfs
```

```
/volume1/VM      10.0.1.0/24
```

10.7.4.2 Defining the pool on the target hosts

On each host where you want to migrate the VM Guest, the pool must be defined to be able to access the volume (that contains the Guest image). Our NFS server IP address is 10.0.1.99, its share is the `/volume1/VM` directory, and we want to get it mounted in the `/var/lib/libvirt/images/VM` directory. The pool name is *VM*. To define this pool, create a `VM.xml` file with the following content:

```
<pool type='netfs'>
  <name>VM</name>
  <source>
    <host name='10.0.1.99'/>
    <dir path='/volume1/VM'/>
    <format type='auto'/>
  </source>
  <target>
    <path>/var/lib/libvirt/images/VM</path>
    <permissions>
      <mode>0755</mode>
      <owner>-1</owner>
      <group>-1</group>
    </permissions>
  </target>
  </pool>
```

Then load it into `libvirt` using the **`pool-define`** command:

```
# virsh pool-define VM.xml
```

An alternative way to define this pool is to use the **`virsh`** command:

```
# virsh pool-define-as VM --type netfs --source-host 10.0.1.99 \
     --source-path /volume1/VM --target /var/lib/libvirt/images/VM
Pool VM created
```

The following commands assume that you are in the interactive shell of **`virsh`** which can also be reached by using the command **`virsh`** without any arguments. Then the pool can be set to start automatically at host boot (autostart option):

```
virsh # pool-autostart VM
Pool VM marked as autostarted
```

To disable the autostart:

```
virsh # pool-autostart VM --disable
Pool VM unmarked as autostarted
```

Check if the pool is present:

```
virsh # pool-list --all
 Name                 State      Autostart
-------------------------------------------
 default              active     yes
 VM                   active     yes

virsh # pool-info VM
Name:           VM
UUID:           42efe1b3-7eaa-4e24-a06a-ba7c9ee29741
State:          running
Persistent:     yes
Autostart:      yes
Capacity:       2,68 TiB
Allocation:     2,38 TiB
Available:      306,05 GiB
```

Warning: Pool needs to exist on all target hosts

Remember: this pool must be defined on each host where you want to be able to migrate your VM Guest.

10.7.4.3 Creating the volume

The pool has been defined—now we need a volume which contains the disk image:

```
virsh # vol-create-as VM sled12.qcow2 8G --format qcow2
Vol sled12.qcow2 created
```

The volume names shown are used later to install the guest with virt-install.

10.7.4.4 Creating the VM Guest

Let's create a openSUSE Leap VM Guest with the **`virt-install`** command. The *VM* pool is specified with the **`--disk`** option, *cache=none* is recommended if you do not want to use the **`--unsafe`** option while doing the migration.

```
# virt-install --connect qemu:///system --virt-type kvm --name \
   sled12 --memory 1024 --disk vol=VM/sled12.qcow2,cache=none --cdrom \
   /mnt/install/ISO/SLE-12-Desktop-DVD-x86_64-Build0327-Media1.iso --graphics \
   vnc --os-variant sled12
Starting install...
Creating domain...
```

10.7.4.5 Migrate the VM Guest

Everything is ready to do the migration now. Run the **`migrate`** command on the VM Host Server that is currently hosting the VM Guest, and choose the destination.

```
virsh # migrate --live sled12 --verbose qemu+ssh://IP/Hostname/system
Password:
Migration: [ 12 %]
```

10.8 Monitoring

10.8.1 Monitoring with Virtual Machine Manager

After starting Virtual Machine Manager and connecting to the VM Host Server, a CPU usage graph of all the running guests is displayed.

It is also possible to get information about disk and network usage with this tool, however, you must first activate this in *Preferences*:

1. Run **`virt-manager`**.
2. Select *Edit* › *Preferences*.
3. Change the tab from *General* to *Polling*.
4. Activate the check boxes for the kind of activity you want to see: *Poll Disk I/O*, *Poll Network I/O*, and *Poll Memory stats*.
5. If desired, also change the update interval using *Update status every n seconds*.
6. Close the *Preferences* dialog.

7. Activate the graphs that should be displayed under *View* › *Graph*.

Afterward, the disk and network statistics are also displayed in the main window of the Virtual Machine Manager.

More precise data is available from the VNC window. Open a VNC window as described in *Section 10.2.1, “Opening a graphical console”*. Choose *Details* from the toolbar or the *View* menu. The statistics are displayed from the *Performance* entry of the left-hand tree menu.

10.8.2 Monitoring with `virt-top`

`virt-top` is a command line tool similar to the well-known process monitoring tool **`top`**. **`virt-top`** uses libvirt and therefore is capable of showing statistics for VM Guests running on different hypervisors. It is recommended to use **`virt-top`** instead of hypervisor-specific tools like **`xentop`**.

By default **`virt-top`** shows statistics for all running VM Guests. Among the data that is displayed is the percentage of memory used (`%MEM`) and CPU (`%CPU`) and the uptime of the guest (`TIME`). The data is updated regularly (every three seconds by default). The following shows the output on a VM Host Server with seven VM Guests, four of them inactive:

```
virt-top 13:40:19 - x86_64 8/8CPU 1283MHz 16067MB 7.6% 0.5%
7 domains, 3 active, 3 running, 0 sleeping, 0 paused, 4 inactive D:0 O:0 X:0
CPU: 6.1%  Mem: 3072 MB (3072 MB by guests)

   ID S RDRQ WRRQ RXBY TXBY %CPU %MEM    TIME   NAME
    7 R  123    1  18K  196  5.8  6.0   0:24.35 sled12_sp1
    6 R    1    0  18K    0  0.2  6.0   0:42.51 sles12_sp1
    5 R    0    0  18K    0  0.1  6.0  85:45.67 opensuse_leap
    -                                           (Ubuntu_1410)
    -                                           (debian_780)
    -                                           (fedora_21)
    -                                           (sles11sp3)
```

By default the output is sorted by ID. Use the following key combinations to change the sort field:

Shift–**P**: CPU usage

Shift–**M**: Total memory allocated by the guest

Shift–**T**: Time

Shift–**I**: ID

To use any other field for sorting, press **Shift**–**F** and select a field from the list. To toggle the sort order, use **Shift**–**R**.

`virt-top` also supports different views on the VM Guests data, which can be changed on-the-fly by pressing the following keys:

`0` : default view
`1` : show physical CPUs
`2` : show network interfaces
`3` : show virtual disks

`virt-top` supports more hot keys to change the view of the data and many command line switches that affect the behavior of the program. For more information, see `man 1 virt-top`.

10.8.3 Monitoring with `kvm_stat`

`kvm_stat` can be used to trace KVM performance events. It monitors `/sys/kernel/debug/kvm`, so it needs the debugfs to be mounted. On openSUSE Leap it should be mounted by default. In case it is not mounted, use the following command:

```
> sudo mount -t debugfs none /sys/kernel/debug
```

`kvm_stat` can be used in three different modes:

```
kvm_stat                    # update in 1 second intervals
kvm_stat -1                 # 1 second snapshot
kvm_stat -l > kvmstats.log  # update in 1 second intervals in log format
                            # can be imported to a spreadsheet
```

EXAMPLE 10.1: TYPICAL OUTPUT OF `kvm_stat`

```
kvm statistics

 efer_reload                   0       0
 exits                  11378946  218130
 fpu_reload                62144     152
 halt_exits               414866     100
 halt_wakeup              260358      50
 host_state_reload        539650     249
 hypercalls                    0       0
 insn_emulation          6227331  173067
 insn_emulation_fail           0       0
 invlpg                   227281      47
 io_exits                 113148      18
 irq_exits                168474     127
 irq_injections           482804     123
```

```
irq_window               51270      18
largepages                   0       0
mmio_exits                6925       0
mmu_cache_miss           71820      19
mmu_flooded              35420       9
mmu_pde_zapped           64763      20
mmu_pte_updated              0       0
mmu_pte_write           213782      29
mmu_recycled                 0       0
mmu_shadow_zapped       128690      17
mmu_unsync                  46      -1
nmi_injections               0       0
nmi_window                   0       0
pf_fixed               1553821     857
pf_guest               1018832     562
remote_tlb_flush        174007      37
request_irq                  0       0
signal_exits                 0       0
tlb_flush               394182     148
```

See http://clalance.blogspot.com/2009/01/kvm-performance-tools.html ↗ for further information on how to interpret these values.

11 Connecting and authorizing

Managing several VM Host Servers, each hosting multiple VM Guests, quickly becomes difficult. One benefit of `libvirt` is the ability to connect to several VM Host Servers at once, providing a single interface to manage all VM Guests and to connect to their graphical console.

To ensure only authorized users can connect, `libvirt` offers several connection types (via TLS, SSH, Unix sockets, and TCP) that can be combined with different authorization mechanisms (socket, Polkit, SASL and Kerberos).

11.1 Authentication

The power to manage VM Guests and to access their graphical console is something that should be restricted to a well-defined circle of persons. To achieve this goal, you can use the following authentication techniques on the VM Host Server:

- Access control for Unix sockets with permissions and group ownership. This method is available for `libvirtd` connections only.
- Access control for Unix sockets with Polkit. This method is available for local `libvirtd` connections only.
- User name and password authentication with SASL (Simple Authentication and Security Layer). This method is available for both `libvirtd` and VNC connections. Using SASL does not require real user accounts on the server, since it uses its own database to store user names and passwords. Connections authenticated with SASL are encrypted.
- Kerberos authentication. This method, available for `libvirtd` connections only, is not covered in this manual. Refer to https://libvirt.org/auth.html#ACL_server_kerberos ↗ for details.
- Single password authentication. This method is available for VNC connections only.

Important: Authentication for `libvirtd` and VNC needs to be configured separately

Access to the VM Guest's management functions (via `libvirtd`) and to its graphical console always needs to be configured separately. When restricting access to the management tools, these restrictions do *not* automatically apply to VNC connections!

When accessing VM Guests from remote via TLS/SSL connections, access can be indirectly controlled on each client by restricting read permissions to the certificate's key file to a certain group. See *Section 11.3.2.5, “Restricting access (security considerations)”* for details.

11.1.1 `libvirtd` authentication

`libvirtd` authentication is configured in `/etc/libvirt/libvirtd.conf`. The configuration made here applies to all `libvirt` tools such as the Virtual Machine Manager or **`virsh`**.

`libvirt` offers two sockets: a read-only socket for monitoring purposes and a read-write socket to be used for management operations. Access to both sockets can be configured independently. By default, both sockets are owned by `root.root`. Default access permissions on the read-write socket are restricted to the user `root` (`0700`) and fully open on the read-only socket (`0777`).

The following instructions describe how to configure access permissions for the read-write socket. The same instructions also apply to the read-only socket. All configuration steps need to be carried out on the VM Host Server.

Note: Default authentication settings on openSUSE Leap

The default authentication method on openSUSE Leap is access control for Unix sockets. Only the user `root` may authenticate. When accessing the `libvirt` tools as a non-root user directly on the VM Host Server, you need to provide the `root` password through Polkit once. You are then granted access for the current and for future sessions.

Alternatively, you can configure `libvirt` to allow “system” access to non-privileged users. See *Section 11.2.1, ““system” access for non-privileged users”* for details.

RECOMMENDED AUTHORIZATION METHODS

Local connections

Section 11.1.1.2, “Local access control for Unix sockets with Polkit”

Section 11.1.1.1, “Access control for Unix sockets with permissions and group ownership”

Remote tunnel over SSH

Section 11.1.1.1, “Access control for Unix sockets with permissions and group ownership”

Remote TLS/SSL connection

Section 11.1.1.3, “User name and password authentication with SASL” none (access controlled on the client side by restricting access to the certificates)

11.1.1.1 Access control for Unix sockets with permissions and group ownership

To grant access for non- `root` accounts, configure the sockets to be owned and accessible by a certain group (`libvirt` in the following example). This authentication method can be used for local and remote SSH connections.

1. In case it does not exist, create the group that should own the socket:

   ```
   > sudo groupadd libvirt
   ```

   Important: Group needs to exist

   The group must exist before restarting `libvirtd` . If not, the restart fails.

2. Add the desired users to the group:

   ```
   > sudo usermod --append --groups libvirt tux
   ```

3. Change the configuration in `/etc/libvirt/libvirtd.conf` as follows:

   ```
   unix_sock_group = "libvirt"❶
   unix_sock_rw_perms = "0770"❷
   auth_unix_rw = "none"❸
   ```

   ❶ Group ownership is set to the group `libvirt` .

   ❷ Sets the access permissions for the socket (`srwxrwx---`).

   ❸ Disables other authentication methods (Polkit or SASL). Access is solely controlled by the socket permissions.

4. Restart `libvirtd` :

   ```
   > sudo systemctl start libvirtd
   ```

11.1.1.2 Local access control for Unix sockets with Polkit

Access control for Unix sockets with Polkit is the default authentication method on openSUSE Leap for non-remote connections. Therefore, no `libvirt` configuration changes are needed. With Polkit authorization enabled, permissions on both sockets default to `0777` and each application trying to access a socket needs to authenticate via Polkit.

Important: Polkit authentication for local connections only

Authentication with Polkit can only be used for local connections on the VM Host Server itself, since Polkit does not handle remote authentication.

Two policies for accessing `libvirt`'s sockets exist:

- *org.libvirt.unix.monitor*: accessing the read-only socket
- *org.libvirt.unix.manage*: accessing the read-write socket

By default, the policy for accessing the read-write socket is to authenticate with the `root` password once and grant the privilege for the current and for future sessions.

To grant users access to a socket without having to provide the `root` password, you need to create a rule in `/etc/polkit-1/rules.d`. Create the file `/etc/polkit-1/rules.d/10-grant-libvirt` with the following content to grant access to the read-write socket to all members of the group `libvirt`:

```
polkit.addRule(function(action, subject) {
  if (action.id == "org.libvirt.unix.manage" && subject.isInGroup("libvirt")) {
    return polkit.Result.YES;
  }
});
```

11.1.1.3 User name and password authentication with SASL

SASL provides user name and password authentication and data encryption (digest-md5, by default). Since SASL maintains its own user database, the users do not need to exist on the VM Host Server. SASL is required by TCP connections and on top of TLS/SSL connections.

Important: Plain TCP and SASL with digest-md5 encryption

Using digest-md5 encryption on an otherwise not encrypted TCP connection does not provide enough security for production environments. It is recommended to only use it in testing environments.

Tip: SASL authentication on top of TLS/SSL

Access from remote TLS/SSL connections can be indirectly controlled on the *client side* by restricting access to the certificate's key file. However, this may prove error-prone when dealing with many clients. Using SASL with TLS adds security by additionally controlling access on the server side.

To configure SASL authentication, proceed as follows:

1. Change the configuration in `/etc/libvirt/libvirtd.conf` as follows:

   a. To enable SASL for TCP connections:

   ```
   auth_tcp = "sasl"
   ```

   b. To enable SASL for TLS/SSL connections:

   ```
   auth_tls = "sasl"
   ```

2. Restart `libvirtd`:

   ```
   > sudo systemctl restart libvirtd
   ```

3. The libvirt SASL configuration file is located at `/etc/sasl2/libvirtd.conf`. Normally, there is no need to change the defaults. However, if using SASL on top of TLS, you may turn off session encryption to avoid additional overhead (TLS connections are already encrypted) by commenting the line setting the `mech_list` parameter. Only do this for TLS/SASL. For TCP connections, this parameter must be set to digest-md5.

   ```
   #mech_list: digest-md5
   ```

4. By default, no SASL users are configured, so no logins are possible. Use the following commands to manage users:

   Add the user `tux`

   ```
   saslpasswd2 -a libvirt tux
   ```

   Delete the user `tux`

   ```
   saslpasswd2 -a libvirt -d tux
   ```

   List existing users

   ```
   sasldblistusers2 -f /etc/libvirt/passwd.db
   ```

Tip: **`virsh`** and SASL authentication

When using SASL authentication, you are prompted for a user name and password every time you issue a **`virsh`** command. Avoid this by using **`virsh`** in shell mode.

11.1.2 VNC authentication

Since access to the graphical console of a VM Guest is not controlled by `libvirt`, but by the specific hypervisor, it is always necessary to additionally configure VNC authentication. The main configuration file is `/etc/libvirt/<hypervisor>.conf`. This section describes the QEMU/KVM hypervisor, so the target configuration file is `/etc/libvirt/qemu.conf`.

Note: VNC authentication for Xen

In contrast with KVM, Xen does not yet offer VNC authentication more sophisticated than setting a password on a per-VM basis. See the `<graphics type='vnc'...` `libvirt` configuration option below.

Two authentication types are available: SASL and single-password authentication. If you are using SASL for `libvirt` authentication, it is strongly recommended to use it for VNC authentication as well—it is possible to share the same database.

A third method to restrict access to the VM Guest is to enable the use of TLS encryption on the VNC server. This requires the VNC clients to have access to x509 client certificates. By restricting access to these certificates, access can indirectly be controlled on the client side. Refer to *Section 11.3.2.4.2, “VNC over TLS/SSL: client configuration”* for details.

11.1.2.1 User name and password authentication with SASL

SASL provides user name and password authentication and data encryption. Since SASL maintains its own user database, the users do not need to exist on the VM Host Server. As with SASL authentication for `libvirt`, you may use SASL on top of TLS/SSL connections. Refer to *Section 11.3.2.4.2, “VNC over TLS/SSL: client configuration”* for details on configuring these connections.

To configure SASL authentication for VNC, proceed as follows:

1. Create a SASL configuration file. It is recommended to use the existing `libvirt` file. If you have already configured SASL for `libvirt` and are planning to use the same settings, including the same user name and password database, a simple link is suitable:

   ```
   > sudo ln -s /etc/sasl2/libvirt.conf /etc/sasl2/qemu.conf
   ```

   If are setting up SASL for VNC only or you are planning to use a different configuration than for `libvirt`, copy the existing file to use as a template:

   ```
   > sudo cp /etc/sasl2/libvirt.conf /etc/sasl2/qemu.conf
   ```

   Then edit it according to your needs.

2. Change the configuration in `/etc/libvirt/qemu.conf` as follows:

   ```
   vnc_listen = "0.0.0.0"
   vnc_sasl = 1
   sasldb_path: /etc/libvirt/qemu_passwd.db
   ```

   The first parameter enables VNC to listen on all public interfaces (rather than to the local host only), and the second parameter enables SASL authentication.

3. By default, no SASL users are configured, so no logins are possible. Use the following commands to manage users:

   Add the user `tux`

   ```
   > saslpasswd2 -f /etc/libvirt/qemu_passwd.db -a qemu tux
   ```

Delete the user `tux`

```
> saslpasswd2 -f /etc/libvirt/qemu_passwd.db -a qemu -d tux
```

List existing users

```
> sasldblistusers2 -f /etc/libvirt/qemu_passwd.db
```

4. Restart `libvirtd`:

```
> sudo systemctl restart libvirtd
```

5. Restart all VM Guests that have been running before changing the configuration. VM Guests that have not been restarted cannot use SASL authentication for VNC connects.

Note: Supported VNC viewers

SASL authentication is currently supported by Virtual Machine Manager and **`virt-viewer`**. Both viewers also support TLS/SSL connections.

11.1.2.2 Single password authentication

Access to the VNC server may also be controlled by setting a VNC password. You can either set a global password for all VM Guests or set individual passwords for each guest. The latter requires editing the VM Guest's configuration files.

Note: Always set a global password

If you are using single password authentication, it is good practice to set a global password even if setting passwords for each VM Guest. This protects your virtual machines with a “fallback” password if you forget to set a per-machine password. The global password is only used if no other password is set for the machine.

PROCEDURE 11.1: SETTING A GLOBAL VNC PASSWORD

1. Change the configuration in `/etc/libvirt/qemu.conf` as follows:

```
vnc_listen = "0.0.0.0"
```

```
vnc_password = "PASSWORD"
```

The first parameter enables VNC to listen on all public interfaces (rather than to the local host only), and the second parameter sets the password. The maximum length of the password is eight characters.

2. Restart `libvirtd`:

```
> sudo systemctl restart libvirtd
```

3. Restart all VM Guests that have been running before changing the configuration. VM Guests that have not been restarted cannot use password authentication for VNC connects.

PROCEDURE 11.2: SETTING A VM GUEST SPECIFIC VNC PASSWORD

1. Change the configuration in `/etc/libvirt/qemu.conf` as follows to enable VNC to listen on all public interfaces (rather than to the local host only).

```
vnc_listen = "0.0.0.0"
```

2. Open the VM Guest's XML configuration file in an editor. Replace *`VM_NAME`* in the following example with the name of the VM Guest. The editor that is used defaults to `$EDITOR`. If that variable is not set, **`vi`** is used.

```
> virsh edit VM_NAME
```

3. Search for the element `<graphics>` with the attribute `type='vnc'`, for example:

```
<graphics type='vnc' port='-1' autoport='yes'/>
```

4. Add the `passwd=PASSWORD` attribute, save the file and exit the editor. The maximum length of the password is eight characters.

```
<graphics type='vnc' port='-1' autoport='yes' passwd='PASSWORD'/>
```

5. Restart `libvirtd`:

```
> sudo systemctl restart libvirtd
```

6. Restart all VM Guests that have been running before changing the configuration. VM Guests that have not been restarted cannot use password authentication for VNC connects.

Warning: Security of the VNC protocol

The VNC protocol is not considered to be safe. Although the password is sent encrypted, it may be vulnerable when an attacker can sniff both the encrypted password and the encryption key. Therefore, it is recommended to use VNC with TLS/SSL or tunneled over SSH. **`virt-viewer`**, Virtual Machine Manager and Remmina (refer to *Book* "Reference", *Chapter 4 "Remote graphical sessions with VNC", Section 4.2 "Remmina: the remote desktop client"*) support both methods.

11.2 Connecting to a VM Host Server

To connect to a hypervisor with `libvirt`, you need to specify a uniform resource identifier (URI). This URI is needed with **`virsh`** and **`virt-viewer`** (except when working as `root` on the VM Host Server) and is optional for the Virtual Machine Manager. Although the latter can be called with a connection parameter (for example, **`virt-manager -c qemu:///system`**), it also offers a graphical interface to create connection URIs. See *Section 11.2.2, "Managing connections with Virtual Machine Manager"* for details.

```
HYPERVISOR❶+PROTOCOL❷://USER@REMOTE❸/CONNECTION_TYPE❹
```

❶ Specify the hypervisor. openSUSE Leap currently supports the following hypervisors: `test` (dummy for testing), `qemu` (KVM), and `xen` (Xen). This parameter is mandatory.

❷ When connecting to a remote host, specify the protocol here. It can be one of: `ssh` (connection via SSH tunnel), `tcp` (TCP connection with SASL/Kerberos authentication), `tls` (TLS/SSL encrypted connection with authentication via x509 certificates).

❸ When connecting to a remote host, specify the user name and the remote host name. If no user name is specified, the user name that has called the command (`$USER`) is used. See below for more information. For TLS connections, the host name needs to be specified exactly as in the x509 certificate.

❹ When connecting to the `QEMU/KVM` hypervisor, two connection types are accepted: `system` for full access rights, or `session` for restricted access. Since `session` access is not supported on openSUSE Leap, this documentation focuses on `system` access.

EXAMPLE HYPERVISOR CONNECTION URIS

`test:///default`

Connect to the local dummy hypervisor. Useful for testing.

`qemu:///system` or `xen:///system`

Connect to the QEMU/Xen hypervisor on the local host having full access (type system).

`qemu+ssh://tux@mercury.example.com/system` or `xen+ssh://tux@mercury.example.com/system`

Connect to the QEMU/Xen hypervisor on the remote host mercury.example.com. The connection is established via an SSH tunnel.

`qemu+tls://saturn.example.com/system` or `xen+tls://saturn.example.com/system`

Connect to the QEMU/Xen hypervisor on the remote host mercury.example.com. The connection is established using TLS/SSL.

For more details and examples, refer to the `libvirt` documentation at https://libvirt.org/uri.html ↗.

Note: User names in URIs

A user name needs to be specified when using Unix socket authentication (regardless of whether using the user/password authentication scheme or Polkit). This applies to all SSH and local connections.

There is no need to specify a user name when using SASL authentication (for TCP or TLS connections) or when doing no additional server-side authentication for TLS connections. With SASL, the user name is not evaluated—you are prompted for an SASL user/password combination in any case.

11.2.1 “system” access for non-privileged users

As mentioned above, a connection to the QEMU hypervisor can be established using two different protocols: `session` and `system`. A “session” connection is spawned with the same privileges as the client program. Such a connection is intended for desktop virtualization, since it is restricted (for example, no USB/PCI device assignments, no virtual network setup, limited remote access to `libvirtd`).

The “system” connection intended for server virtualization has no functional restrictions but is, by default, only accessible by `root`. However, with the addition of the DAC (Discretionary Access Control) driver to `libvirt`, it is now possible to grant non-privileged users “system” access. To grant “system” access to the user `tux`, proceed as follows:

PROCEDURE 11.3: GRANTING “SYSTEM” ACCESS TO A REGULAR USER

1. Enable access via Unix sockets, as described in *Section 11.1.1.1, “Access control for Unix sockets with permissions and group ownership”*. In that example, access to libvirt is granted to all members of the group `libvirt` and `tux` made a member of this group. This ensures that `tux` can connect using **`virsh`** or Virtual Machine Manager.

2. Edit `/etc/libvirt/qemu.conf` and change the configuration as follows:

```
user = "tux"
group = "libvirt"
dynamic_ownership = 1
```

   This ensures that the VM Guests are started by `tux` and that resources bound to the guest (for example virtual disks) can be accessed and modified by `tux`.

3. Make `tux` a member of the group `kvm`:

```
> sudo usermod --append --groups kvm tux
```

   This step is needed to grant access to `/dev/kvm`, which is required to start VM Guests.

4. Restart `libvirtd`:

```
> sudo systemctl restart libvirtd
```

11.2.2 Managing connections with Virtual Machine Manager

The Virtual Machine Manager uses a `Connection` for every VM Host Server it manages. Each connection contains all VM Guests on the respective host. By default, a connection to the local host is already configured and connected.

All configured connections are displayed in the Virtual Machine Manager main window. Active connections are marked with a small triangle, which you can click to fold or unfold the list of VM Guests for this connection.

Inactive connections are listed gray and are marked with `Not Connected`. Either double-click or right-click it and choose *Connect* from the context menu. You can also *Delete* an existing connection from this menu.

Note: Editing existing connections

It is not possible to edit an existing connection. To change a connection, create a new one with the desired parameters and delete the “old” one.

To add a new connection in the Virtual Machine Manager, proceed as follows:

1. Choose *File* › *Add Connection*
2. Choose the host's *Hypervisor* (*Xen* or *QEMU/KVM*)
3. *(Optional)* To set up a remote connection, choose *Connect to remote host*. For more information, see *Section 11.3, “Configuring remote connections”*.
   In case of a remote connection, specify the *Hostname* of the remote machine in the format `USERNAME@REMOTE _HOST`.

   ### Important: Specifying a user name

   There is no need to specify a user name for TCP and TLS connections: in these cases, it is not evaluated. However, for SSH connections, specifying a user name is necessary when you want to connect as a user other than `root`.
4. If you do not want the connection to be automatically started when starting the Virtual Machine Manager, deactivate *Autoconnect*.
5. Finish the configuration by clicking *Connect*.

11.3 Configuring remote connections

A major benefit of `libvirt` is the ability to manage VM Guests on different remote hosts from a central location. This section gives detailed instructions on how to configure server and client to allow remote connections.

11.3.1 Remote tunnel over SSH (qemu+ssh or xen+ssh)

Enabling a remote connection that is tunneled over SSH on the VM Host Server only requires the ability to accept SSH connections. Make sure the SSH daemon is started (**`systemctl status sshd`**) and that the ports for service `SSH` are opened in the firewall.

User authentication for SSH connections can be done using traditional file user/group ownership and permissions as described in *Section 11.1.1.1, "Access control for Unix sockets with permissions and group ownership"*. Connecting as user tux (`qemu+ssh://tuxsIVname;/system` or `xen+ssh://tuxsIVname;/system`) works out of the box and does not require additional configuration on the `libvirt` side.

When connecting via SSH `qemu+ssh://USER@SYSTEM` or `xen+ssh://USER@SYSTEM` you need to provide the password for `USER`. This can be avoided by copying your public key to `~USER/.ssh/authorized_keys` on the VM Host Server as explained in *Book* "Security and Hardening Guide", *Chapter 22 "Securing network operations with OpenSSH", Section 22.6 "Public key authentication"*. Using **`gnome-keyring`** on the machine from which you are connecting adds even more convenience. For more information, see *Book* "Security and Hardening Guide", *Chapter 22 "Securing network operations with OpenSSH", Section 22.9 "Automated public key logins with gnome-keyring"*.

11.3.2 Remote TLS/SSL connection with x509 certificate (qemu+tls or xen+tls)

Using TCP connections with TLS/SSL encryption and authentication via x509 certificates is much more complicated to set up than SSH, but it is a lot more scalable. Use this method if you need to manage several VM Host Servers with a varying number of administrators.

11.3.2.1 Basic concept

TLS (Transport Layer Security) encrypts the communication between two computers by using certificates. The computer starting the connection is always considered the "client", using a "client certificate", while the receiving computer is always considered the "server", using a "server certificate". This scenario applies, for example, if you manage your VM Host Servers from a central desktop.

If connections are initiated from both computers, each needs to have a client *and* a server certificate. This is the case, for example, if you migrate a VM Guest from one host to another.

Each x509 certificate has a matching private key file. Only the combination of certificate and private key file can identify itself correctly. To assure that a certificate was issued by the assumed owner, it is signed and issued by a central certificate called certificate authority (CA). Both the client and the server certificates must be issued by the same CA.

Important: User authentication

Using a remote TLS/SSL connection only ensures that two computers are allowed to communicate in a certain direction. Restricting access to certain users can indirectly be achieved on the client side by restricting access to the certificates. For more information, see *Section 11.3.2.5, "Restricting access (security considerations)"*.

`libvirt` also supports user authentication on the server with SASL. For more information, see *Section 11.3.2.6, "Central user authentication with SASL for TLS sockets"*.

11.3.2.2 Configuring the VM Host Server

The VM Host Server is the machine receiving connections. Therefore, the *server* certificates need to be installed. The CA certificate needs to be installed, too. When the certificates are in place, TLS support can be turned on for `libvirt`.

1. Create the server certificate and export it together with the respective CA certificate.

2. Create the following directories on the VM Host Server:

```
> sudo mkdir -p /etc/pki/CA/ /etc/pki/libvirt/private/
```

Install the certificates as follows:

```
> sudo /etc/pki/CA/cacert.pem
> sudo /etc/pki/libvirt/servercert.pem
> sudo /etc/pki/libvirt/private/serverkey.pem
```

Important: Restrict access to certificates

Make sure to restrict access to certificates, as explained in *Section 11.3.2.5, "Restricting access (security considerations)"*.

3. Enable TLS support by enabling the relevant socket and restarting `libvirtd`:

   ```
   > sudo systemctl stop libvirtd.service
   > sudo systemctl enable --now libvirtd-tls.socket
   > sudo systemctl start libvirtd.service
   ```

4. By default, `libvirt` uses the TCP port 16514 for accepting secure TLS connections. Open this port in the firewall.

Important: Restarting `libvirtd` with TLS enabled

If you enable TLS for `libvirt`, the server certificates need to be in place, otherwise restarting `libvirtd` fails. You also need to restart `libvirtd` in case you change the certificates.

11.3.2.3 Configuring the client and testing the setup

The client is the machine initiating connections. Therefore the *client* certificates need to be installed. The CA certificate needs to be installed, too.

1. Create the client certificate and export it together with the respective CA certificate.

2. Create the following directories on the client:

   ```
   > sudo mkdir -p /etc/pki/CA/ /etc/pki/libvirt/private/
   ```

   Install the certificates as follows:

   ```
   > sudo /etc/pki/CA/cacert.pem
   > sudo /etc/pki/libvirt/clientcert.pem
   > sudo /etc/pki/libvirt/private/clientkey.pem
   ```

   #### Important: Restrict access to certificates

   Make sure to restrict access to certificates, as explained in *Section 11.3.2.5, “Restricting access (security considerations)”*.

3. Test the client/server setup by issuing the following command. Replace *`mercury.example.com`* with the name of your VM Host Server. Specify the same fully qualified host name as used when creating the server certificate.

```
#QEMU/KVM
virsh -c qemu+tls://mercury.example.com/system list --all

#Xen
virsh -c xen+tls://mercury.example.com/system list --all
```

If your setup is correct, you can see a list of all VM Guests registered with `libvirt` on the VM Host Server.

11.3.2.4 Enabling VNC for TLS/SSL connections

Currently, VNC communication over TLS is only supported by a few tools. Common VNC viewers such as **`tightvnc`** or **`tigervnc`** do not support TLS/SSL. The only supported alternative to Virtual Machine Manager and **`virt-viewer`** is **`remmina`** (refer to *Book "Reference", Chapter 4 "Remote graphical sessions with VNC", Section 4.2 "Remmina: the remote desktop client"*).

11.3.2.4.1 VNC over TLS/SSL: VM Host Server configuration

To access the graphical console via VNC over TLS/SSL, you need to configure the VM Host Server as follows:

1. Open ports for the service `VNC` in your firewall.

2. Create a directory `/etc/pki/libvirt-vnc` and link the certificates into this directory as follows:

```
> sudo mkdir -p /etc/pki/libvirt-vnc && cd /etc/pki/libvirt-vnc
> sudo ln -s /etc/pki/CA/cacert.pem ca-cert.pem
> sudo ln -s /etc/pki/libvirt/servercert.pem server-cert.pem
> sudo ln -s /etc/pki/libvirt/private/serverkey.pem server-key.pem
```

3. Edit `/etc/libvirt/qemu.conf` and set the following parameters:

```
vnc_listen = "0.0.0.0"
        vnc_tls = 1
        vnc_tls_x509_verify = 1
```

4. Restart the `libvirtd`:

```
> sudo systemctl restart libvirtd
```

Important: VM Guests need to be restarted

The VNC TLS setting is only set when starting a VM Guest. Therefore, you need to restart all machines that have been running before making the configuration change.

11.3.2.4.2 VNC over TLS/SSL: client configuration

The only action needed on the client side is to place the x509 client certificates in a location recognized by the client of choice. However, Virtual Machine Manager and `virt-viewer` expect the certificates in a different location. Virtual Machine Manager can either read from a system-wide location applying to all users, or from a per-user location. Remmina (refer to *Book "Reference", Chapter 4 "Remote graphical sessions with VNC", Section 4.2 "Remmina: the remote desktop client"*) asks for the location of certificates when initializing the connection to the remote VNC session.

Virtual Machine Manager (`virt-manager`)

To connect to the remote host, Virtual Machine Manager requires the setup explained in *Section 11.3.2.3, "Configuring the client and testing the setup"*. To be able to connect via VNC, the client certificates also need to be placed in the following locations:

System-wide location

`/etc/pki/CA/cacert.pem`
`/etc/pki/libvirt-vnc/clientcert.pem`
`/etc/pki/libvirt-vnc/private/clientkey.pem`

Per-user location

`/etc/pki/CA/cacert.pem`
`~/.pki/libvirt-vnc/clientcert.pem`
`~/.pki/libvirt-vnc/private/clientkey.pem`

`virt-viewer`

`virt-viewer` only accepts certificates from a system-wide location:

`/etc/pki/CA/cacert.pem`
`/etc/pki/libvirt-vnc/clientcert.pem`
`/etc/pki/libvirt-vnc/private/clientkey.pem`

Important: Restrict access to certificates

Make sure to restrict access to certificates, as explained in *Section 11.3.2.5, “Restricting access (security considerations)”*.

11.3.2.5 Restricting access (security considerations)

Each x509 certificate consists of two pieces: the public certificate and a private key. A client can only authenticate using both pieces. Therefore, any user that has read access to the client certificate and its private key can access your VM Host Server. On the other hand, an arbitrary machine equipped with the full server certificate can pretend to be the VM Host Server. Since this is not desirable, access to at least the private key files needs to be restricted as much as possible. The easiest way to control access to a key file is to use access permissions.

Server certificates

Server certificates need to be readable for QEMU processes. On openSUSE Leap QEMU, processes started from `libvirt` tools are owned by `root`, so it is sufficient if the `root` can read the certificates:

```
> chmod 700 /etc/pki/libvirt/private/
> chmod 600 /etc/pki/libvirt/private/serverkey.pem
```

If you change the ownership for QEMU processes in `/etc/libvirt/qemu.conf`, you also need to adjust the ownership of the key file.

System-wide client certificates

To control access to a key file that is available system-wide, restrict read access to a certain group, so that only members of that group can read the key file. In the following example, a group `libvirt` is created, and group ownership of the `clientkey.pem` file and its parent directory is set to `libvirt`. Afterward, the access permissions are restricted to owner and group. Finally, the user `tux` is added to the group `libvirt`, and thus can access the key file.

```
CERTPATH="/etc/pki/libvirt/"
# create group libvirt
groupadd libvirt
# change ownership to user root and group libvirt
chown root.libvirt $CERTPATH/private $CERTPATH/clientkey.pem
# restrict permissions
chmod 750 $CERTPATH/private
chmod 640 $CERTPATH/private/clientkey.pem
# add user tux to group libvirt
usermod --append --groups libvirt tux
```

Per-user certificates

User-specific client certificates for accessing the graphical console of a VM Guest via VNC need to be placed in the user's home directory in `~/.pki`. Contrary to SSH, for example, the VNC viewer using these certificates does not check the access permissions of the private key file. Therefore, it is solely the user's responsibility to make sure the key file is not readable by others.

11.3.2.5.1 Restricting access from the server side

By default, every client that is equipped with appropriate client certificates may connect to a VM Host Server accepting TLS connections. Therefore, it is possible to use additional server-side authentication with SASL as described in *Section 11.1.1.3, “User name and password authentication with SASL”*.

It is also possible to restrict access with a allowlist of DNs (distinguished names), so only clients with a certificate matching a DN from the list can connect.

Add a list of allowed DNs to `tls_allowed_dn_list` in `/etc/libvirt/libvirtd.conf`. This list may contain wild cards. Do not specify an empty list, since that would result in refusing all connections.

```
tls_allowed_dn_list = [
   "C=US,L=Provo,O=SUSE Linux Products GmbH,OU=*,CN=venus.example.com,EMAIL=*",
   "C=DE,L=Nuremberg,O=SUSE Linux Products GmbH,OU=Documentation,CN=*"]
```

Get the distinguished name of a certificate with the following command:

```
> certtool -i --infile /etc/pki/libvirt/clientcert.pem | grep "Subject:"
```

Restart `libvirtd` after having changed the configuration:

```
> sudo systemctl restart libvirtd
```

11.3.2.6 Central user authentication with SASL for TLS sockets

A direct user authentication via TLS is not possible—this is handled indirectly on each client via the read permissions for the certificates as explained in *Section 11.3.2.5, “Restricting access (security considerations)”*. However, if a central, server-based user authentication is needed, `libvirt` also allows to use SASL (Simple Authentication and Security Layer) on top of TLS for direct user authentication. See *Section 11.1.1.3, “User name and password authentication with SASL”* for configuration details.

11.3.2.7 Troubleshooting

11.3.2.7.1 Virtual Machine Manager/virsh cannot connect to server

Check the following in the given order:

Is it a firewall issue (TCP port 16514 needs to be open on the server)?
Is the client certificate (certificate and key) readable by the user that has started Virtual Machine Manager/ **virsh** ?
Has the same full qualified host name as in the server certificate been specified with the connection?
Is TLS enabled on the server (`listen_tls = 1`)?
Has `libvirtd` been restarted on the server?

11.3.2.7.2 VNC connection fails

Ensure that you can connect to the remote server using Virtual Machine Manager. If so, check whether the virtual machine on the server has been started with TLS support. The virtual machine's name in the following example is `sles` .

```
> ps ax | grep qemu | grep "\-name sles" | awk -F" -vnc " '{ print FS $2 }'
```

If the output does not begin with a string similar to the following, the machine has not been started with TLS support and must be restarted.

```
 -vnc 0.0.0.0:0,tls,x509verify=/etc/pki/libvirt
```

12 Advanced storage topics

This chapter introduces advanced topics about manipulating storage from the perspective of the VM Host Server.

12.1 Locking disk files and block devices with `virtlockd`

Locking block devices and disk files prevents concurrent writes to these resources from different VM Guests. It provides protection against starting the same VM Guest twice, or adding the same disk to two different virtual machines. This reduces the risk of a virtual machine's disk image becoming corrupted because of a wrong configuration.

The locking is controlled by a daemon called `virtlockd`. Since it operates independently from the `libvirtd` daemon, locks endure a crash or a restart of `libvirtd`. Locks even persist during an update of the `virtlockd` itself, since it can re-execute itself. This ensures that VM Guests do *not* need to be restarted upon a `virtlockd` update. `virtlockd` is supported for KVM, QEMU, and Xen.

12.1.1 Enable locking

Locking virtual disks is not enabled by default on openSUSE Leap. To enable and automatically start it upon rebooting, perform the following steps:

1. Edit `/etc/libvirt/qemu.conf` and set

```
lock_manager = "lockd"
```

2. Start the `virtlockd` daemon with the following command:

```
> sudo systemctl start virtlockd
```

3. Restart the `libvirtd` daemon with:

```
> sudo systemctl restart libvirtd
```

4. Make sure `virtlockd` is automatically started when booting the system:

```
> sudo systemctl enable virtlockd
```

12.1.2 Configure locking

By default `virtlockd` is configured to automatically lock all disks configured for your VM Guests. The default setting uses a “direct” lockspace, where the locks are acquired against the actual file paths associated with the VM Guest <disk> devices. For example, `flock(2)` is called directly on `/var/lib/libvirt/images/my-server/disk0.raw` when the VM Guest contains the following <disk> device:

```
<disk type='file' device='disk'>
 <driver name='qemu' type='raw'/>
 <source file='/var/lib/libvirt/images/my-server/disk0.raw'/>
 <target dev='vda' bus='virtio'/>
</disk>
```

The `virtlockd` configuration can be changed by editing the file `/etc/libvirt/qemu-lockd.conf`. It also contains detailed comments with further information. Make sure to activate configuration changes by reloading `virtlockd`:

```
> sudo systemctl reload virtlockd
```

12.1.2.1 Enabling an indirect lockspace

The default configuration of `virtlockd` uses a “direct” lockspace. This means that the locks are acquired against the actual file paths associated with the <disk> devices.

If the disk file paths are not accessible to all hosts, `virtlockd` can be configured to allow an “indirect” lockspace. This means that a hash of the disk image path is used to create a file in the indirect lockspace directory. The locks are then held on these hash files instead of the actual disk file paths. Indirect lockspace is also useful if the file system containing the disk files does not support `fcntl()` locks. An indirect lockspace is specified with the `file_lockspace_dir` setting:

```
file_lockspace_dir = "/MY_LOCKSPACE_DIRECTORY"
```

12.1.2.2 Enable locking on LVM or iSCSI volumes

When wanting to lock virtual disks placed on LVM or iSCSI volumes shared by several hosts, locking needs to be done by UUID rather than by path (which is used by default). Furthermore, the lockspace directory needs to be placed on a shared file system accessible by all hosts sharing the volume. Set the following options for LVM and/or iSCSI:

```
lvm_lockspace_dir = "/MY_LOCKSPACE_DIRECTORY"
iscsi_lockspace_dir = "/MY_LOCKSPACE_DIRECTORY"
```

12.2 Online resizing of guest block devices

Sometimes you need to change—extend or shrink—the size of the block device used by your guest system. For example, when the disk space originally allocated is no longer enough, it is time to increase its size. If the guest disk resides on a *logical volume*, you can resize it while the guest system is running. This is a big advantage over an offline disk resizing (see the **virt-resize** command from the *Section 18.3, “Guestfs tools”* package) as the service provided by the guest is not interrupted by the resizing process. To resize a VM Guest disk, follow these steps:

PROCEDURE 12.1: ONLINE RESIZING OF GUEST DISK

1. Inside the guest system, check the current size of the disk (for example `/dev/vda`).

```
# fdisk -l /dev/vda
Disk /dev/sda: 160.0 GB, 160041885696 bytes, 312581808 sectors
Units = sectors of 1 * 512 = 512 bytes
Sector size (logical/physical): 512 bytes / 512 bytes
I/O size (minimum/optimal): 512 bytes / 512 bytes
```

2. On the host, resize the logical volume holding the `/dev/vda` disk of the guest to the required size, for example 200 GB.

```
# lvresize -L 200G /dev/mapper/vg00-home
Extending logical volume home to 200 GiB
Logical volume home successfully resized
```

3. On the host, resize the block device related to the disk `/dev/mapper/vg00-home` of the guest. You can find the *`DOMAIN_ID`* with **`virsh list`**.

```
# virsh blockresize  --path /dev/vg00/home --size 200G DOMAIN_ID
Block device '/dev/vg00/home' is resized
```

4. Check that the new disk size is accepted by the guest.

   ```
   # fdisk -l /dev/vda
   Disk /dev/sda: 200.0 GB, 200052357120 bytes, 390727260 sectors
   Units = sectors of 1 * 512 = 512 bytes
   Sector size (logical/physical): 512 bytes / 512 bytes
   I/O size (minimum/optimal): 512 bytes / 512 bytes
   ```

12.3 Sharing directories between host and guests (file system pass-through)

libvirt allows to share directories between host and guests using QEMU's file system pass-through (also called VirtFS) feature. Such a directory can be also be accessed by several VM Guests at once and therefore be used to exchange files between VM Guests.

Note: Windows guests and file system pass-through

Sharing directories between VM Host Server and Windows guests via File System Pass-Through does not work, because Windows lacks the drivers required to mount the shared directory.

To make a shared directory available on a VM Guest, proceed as follows:

1. Open the guest's console in Virtual Machine Manager and either choose *View* › *Details* from the menu or click *Show virtual hardware details* in the toolbar. Choose *Add Hardware* › *Filesystem* to open the *Filesystem Passthrough* dialog.

2. *Driver* allows you to choose between a *Handle* or *Path* base driver. The default setting is *Path*. *Mode* lets you choose the security model, which influences the way file permissions are set on the host. Three options are available:

   ***Passthrough* (default)**

   Files on the file system are directly created with the client-user's credentials. This is similar to what NFSv3 is using.

   Squash

   Same as *Passthrough*, but failure of privileged operations like **`chown`** are ignored. This is required when KVM is not run with `root` privileges.

Mapped

Files are created with the file server's credentials (`qemu.qemu`). The user credentials and the client-user's credentials are saved in extended attributes. This model is recommended when host and guest domains should be kept isolated.

3. Specify the path to the directory on the VM Host Server with *Source Path*. Enter a string at *Target Path* to be used as a tag to mount the shared directory. The string of this field is a tag only, not a path on the VM Guest.

4. *Apply* the setting. If the VM Guest is currently running, you need to shut it down to apply the new setting (rebooting the guest is not sufficient).

5. Boot the VM Guest. To mount the shared directory, enter the following command:

```
> sudo mount -t 9p -o trans=virtio,version=9p2000.L,rw TAG /MOUNT_POINT
```

To make the shared directory permanently available, add the following line to the `/etc/fstab` file:

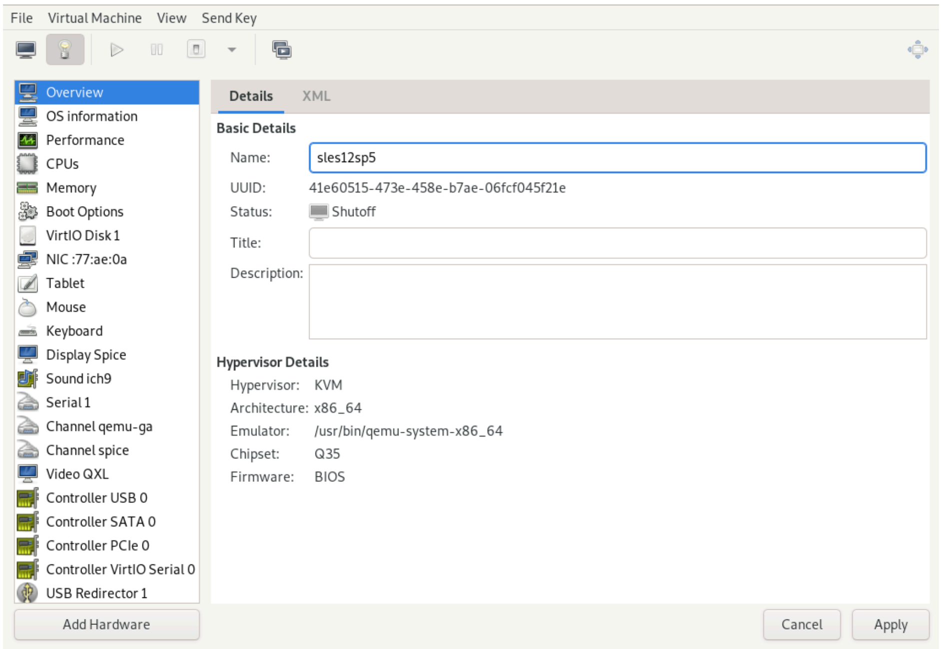
```
TAG   /MOUNT_POINT    9p  trans=virtio,version=9p2000.L,rw    0   0
```

12.4 Using RADOS block devices with `libvirt`

RADOS Block Devices (RBD) store data in a Ceph cluster. They allow snapshotting, replication and data consistency. You can use an RBD from your `libvirt`-managed VM Guests similarly to how you use other block devices.

13 Configuring virtual machines with Virtual Machine Manager

Virtual Machine Manager's *Details* view offers in-depth information about the VM Guest's complete configuration and hardware equipment. Using this view, you can also change the guest configuration or add and modify virtual hardware. To access this view, open the guest's console in Virtual Machine Manager and either choose *View* › *Details* from the menu, or click *Show virtual hardware details* in the toolbar.



Basic Details

Name: sles12sp5
UUID: 41e60515-473e-458e-b7ae-06fcf045f21e
Status: Shutoff
Title:
Description:

Hypervisor Details

Hypervisor: KVM
Architecture: x86_64
Emulator: /usr/bin/qemu-system-x86_64
Chipset: Q35
Firmware: BIOS

FIGURE 13.1: *DETAILS* VIEW OF A VM GUEST

The left panel of the window lists VM Guest overview and already installed hardware. After clicking an item on the list, you can access its detailed settings in the details view. You can change the hardware parameters to match your needs, then click *Apply* to confirm them. Some changes take effect immediately, while others need a reboot of the machine—and `virt-manager` warns you about that fact.

To remove installed hardware from a VM Guest, select the appropriate list entry in the left panel and then click *Remove* in the bottom right of the window.

To add new hardware, click *Add Hardware* below the left panel, then select the type of the hardware you want to add in the *Add New Virtual Hardware* window. Modify its parameters and confirm with *Finish*.

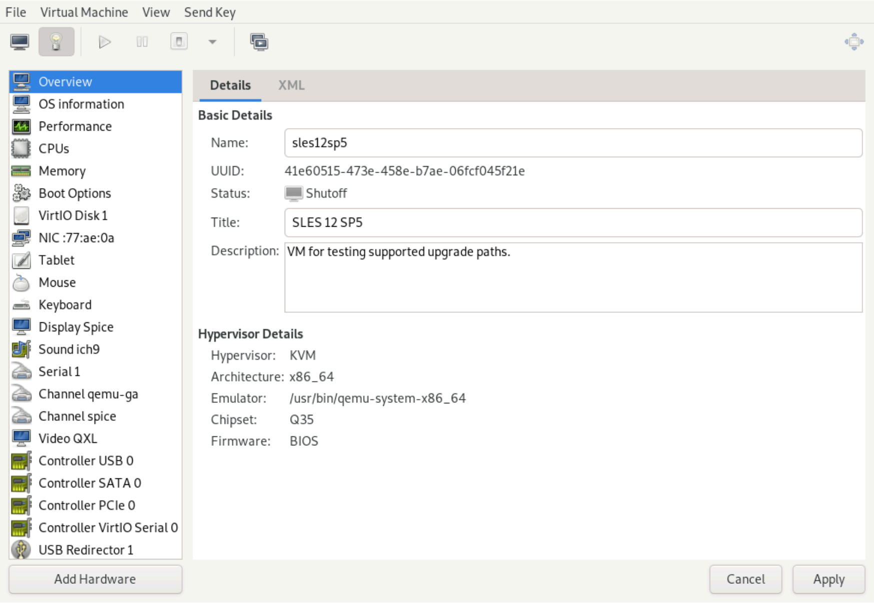
The following sections describe configuration options for the specific hardware type *being added*. They do not focus on modifying an existing piece of hardware, as the options are identical.

13.1 Machine setup

This section describes the setup of the virtualized processor and memory hardware. These components are vital to a VM Guest, therefore you cannot remove them. It also shows how to view the overview and performance information, and how to change boot parameters.

13.1.1 Overview

Overview shows basic details about VM Guest and the hypervisor.



Basic Details

Name: sles12sp5

UUID: 41e60515-473e-458e-b7ae-06fcf045f21e

Status: Shutoff

Title: SLES 12 SP5

Description: VM for testing supported upgrade paths.

Hypervisor Details

Hypervisor: KVM

Architecture: x86_64

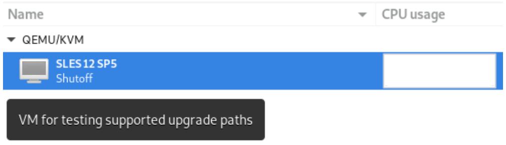
Emulator: /usr/bin/qemu-system-x86_64

Chipset: Q35

Firmware: BIOS

FIGURE 13.2: OVERVIEW DETAILS

Name, *Title*, and *Description* are editable and help you identify VM Guest in the *Virtual Machine Manager* list of machines.



SLES 12 SP5
Shutoff

VM for testing supported upgrade paths

FIGURE 13.3: VM GUEST TITLE AND DESCRIPTION

UUID shows the universally unique identifier of the virtual machine, while *Status* shows its current status—*Running*, *Paused*, or *Shutoff*.

The *Hypervisor Details* section shows the hypervisor type, CPU architecture, used emulator, and chipset type. None of the hypervisor parameters can be changed.

13.1.2 Performance

Performance shows regularly updated charts of CPU and memory usage, and disk and network I/O.

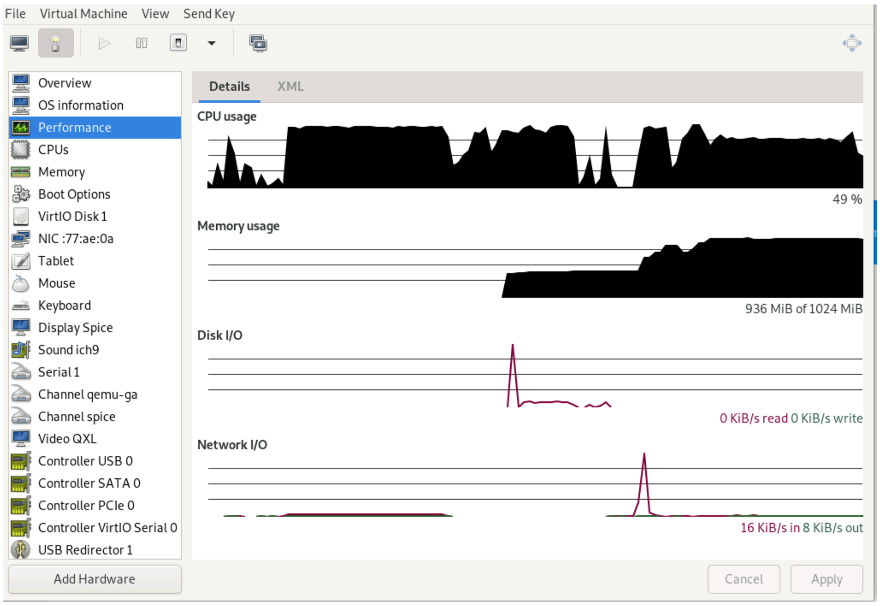
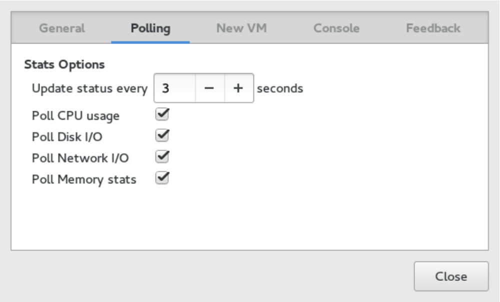


FIGURE 13.4: PERFORMANCE

Tip: Enabling disabled charts

Not all the charts in the *Graph* view are enabled by default. To enable these charts, go to *File* › *View Manager*, then select *Edit* › *Preferences* › *Polling*, and check the charts that you want to see regularly updated.



Stats Options

Update status every 3 seconds

Poll CPU usage ☑

Poll Disk I/O ☑

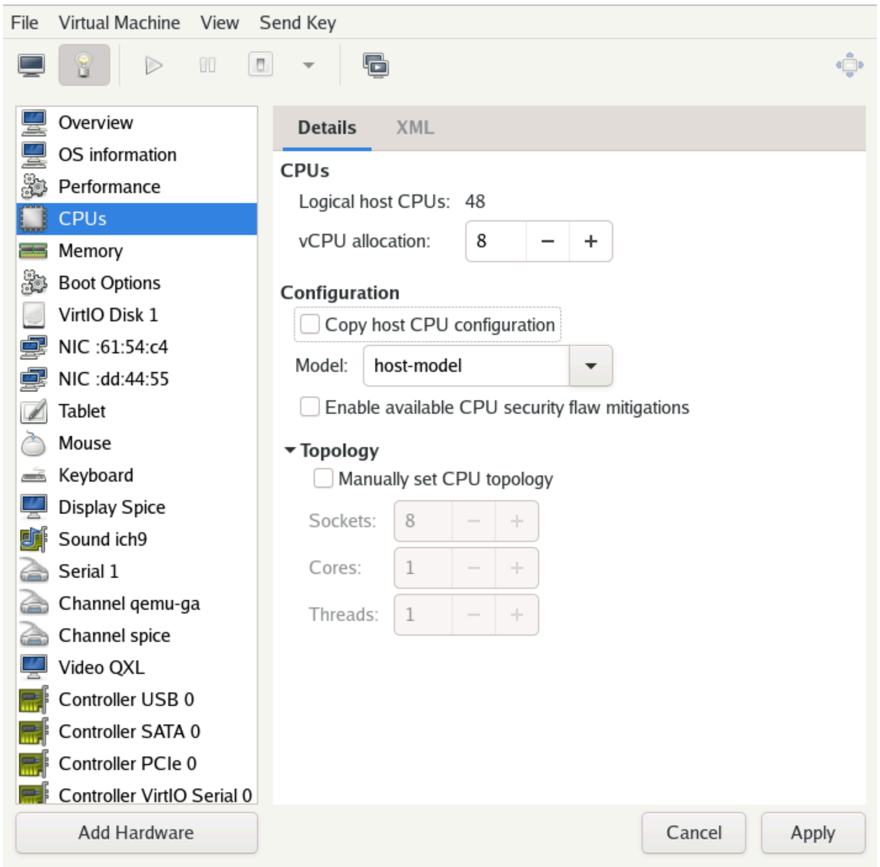
Poll Network I/O ☑

Poll Memory stats ☑

FIGURE 13.5: STATISTICS CHARTS

13.1.3 Processor

CPU includes detailed information about VM Guest processor configuration.



CPUs

Logical host CPUs: 48

vCPU allocation: 8

Configuration

☐ Copy host CPU configuration

Model: host-model

☐ Enable available CPU security flaw mitigations

Topology

☐ Manually set CPU topology

Sockets: 8

Cores: 1

Threads: 1

FIGURE 13.6: PROCESSOR VIEW

In the *CPUs* section, you can configure the number of virtual CPUs allocated to the VM Guest. *Logical host CPUs* shows the number of online and usable CPUs on the VM Host Server.

The *Configuration* section lets you configure the CPU model and topology.

When activated, the *Copy host CPU configuration* option uses the host CPU model for VM Guest. You can see the details of the host CPU model in the output of the **`virsh capabilities`** command. When deactivated, the CPU model needs to be specified from the models available in the drop-down box.

The host CPU model provides a good trade-off between CPU features and the ability to migrate the VM Guest. `libvirt` does not model every aspect of each CPU, so the VM Guest CPU does not match the VM Host Server CPU exactly. But the ABI provided to the VM Guest is reproducible and during migration the complete CPU model definition is transferred to the destination VM Host Server, ensuring the migrated VM Guest can see the exact same CPU model on the destination.

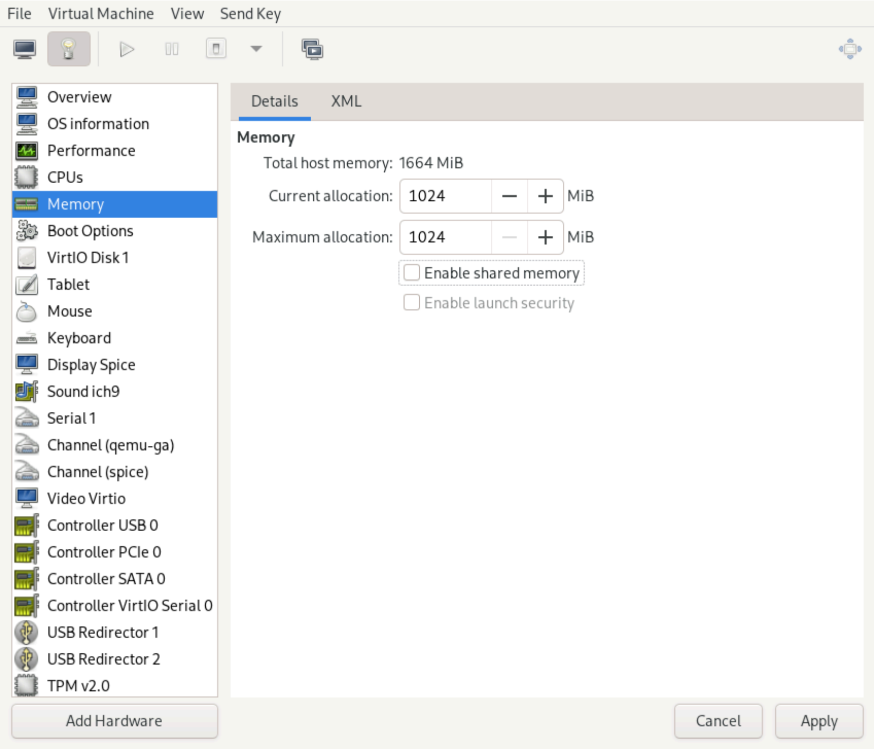
The `host-passthrough` model provides the VM Guest with a CPU that is exactly the same as the VM Host Server CPU. This can be useful when the VM Guest workload requires CPU features not available in `libvirt`'s simplified `host-model` CPU. The `host-passthrough` model comes with the disadvantage of reduced migration capability. A VM Guest with `host-passthrough` model CPU can only be migrated to a VM Host Server with identical hardware.

For more information on `libvirt`'s CPU model and topology options, see the *CPU model and topology* documentation at https://libvirt.org/formatdomain.html#cpu-model-and-topology ↗.

After you activate *Manually set CPU topology*, you can specify a custom number of sockets, cores and threads for the CPU.

13.1.4 Memory

Memory contains information about the memory that is available to VM Guest.



Memory

Total host memory: 1664 MiB

Current allocation: 1024 MiB

Maximum allocation: 1024 MiB

□ Enable shared memory

□ Enable launch security

FIGURE 13.7: MEMORY VIEW

Total host memory

Total amount of memory installed on VM Host Server.

Current allocation

The amount of memory currently available to VM Guest. You can hotplug more memory by increasing this value up to the value of *Maximum allocation*.

Enable shared memory

Specify if the virtual machine can use shared memory via the `memfd` backed. It is a requirement for using the *virtiofs* file system. Find more details in https://libvirt.org/kbase/virtiofs.html ↗.

Maximum allocation

The maximum value to which you can hotplug the currently available memory. Any change to this value takes effect after the next VM Guest reboot.

Enable launch security

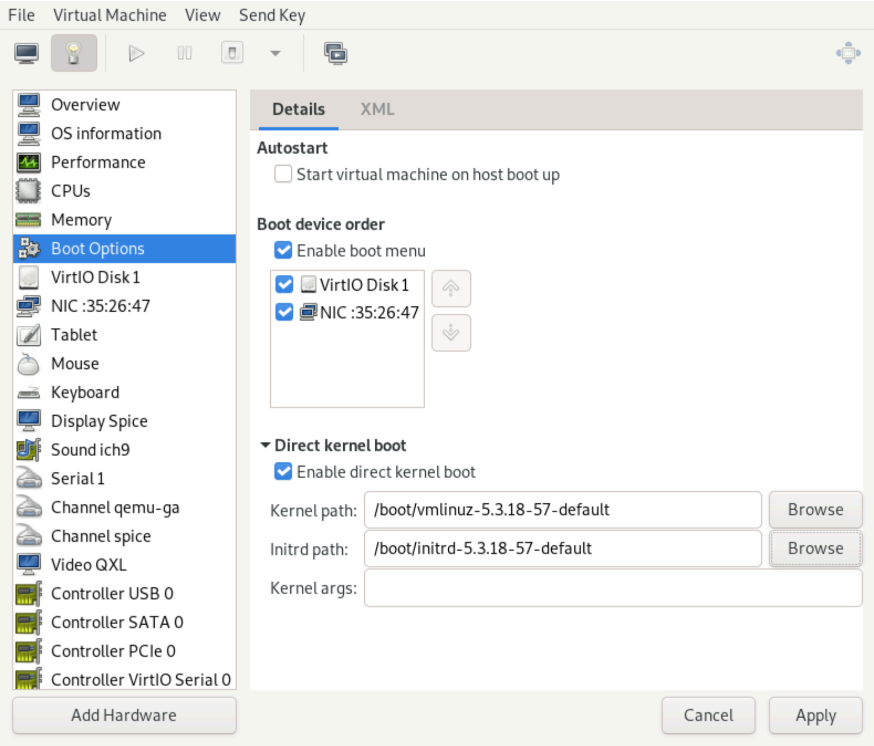
If the VM Host Server supports AMD-SEV technology, activating this option enables a secured guest with encrypted memory. This option requires a virtual machine with chipset type Q35.

Important: Large memory VM Guests

VM Guests with memory requirements of 4 TB or more must either use the `host-passthrough` CPU mode, or explicitly specify the virtual CPU address size when using `host-model` or `custom` CPU modes. The default virtual CPU address size for these modes may not be sufficient for memory configurations of 4 TB or more. The address size can only be specified by editing the VM Guests XML configuration. See *Section 14.6, “Configuring memory allocation”* for more information on specifying virtual CPU address size.

13.1.5 Boot options

Boot Options introduces options affecting the VM Guest boot process.



Autostart

☐ Start virtual machine on host boot up

Boot device order

☑ Enable boot menu

☑ VirtIO Disk 1

☑ NIC :35:26:47

Direct kernel boot

☑ Enable direct kernel boot

Kernel path: /boot/vmlinuz-5.3.18-57-default

Initrd path: /boot/initrd-5.3.18-57-default

Kernel args:

FIGURE 13.8: BOOT OPTIONS

In the *Autostart* section, you can specify whether the virtual machine should automatically start during the VM Host Server boot phase.

In the *Boot device order*, activate the devices used for booting VM Guest. You can change their order with the up and down arrow buttons on the right side of the list. To choose from a list of bootable devices on VM Guest start, activate *Enable boot menu*.

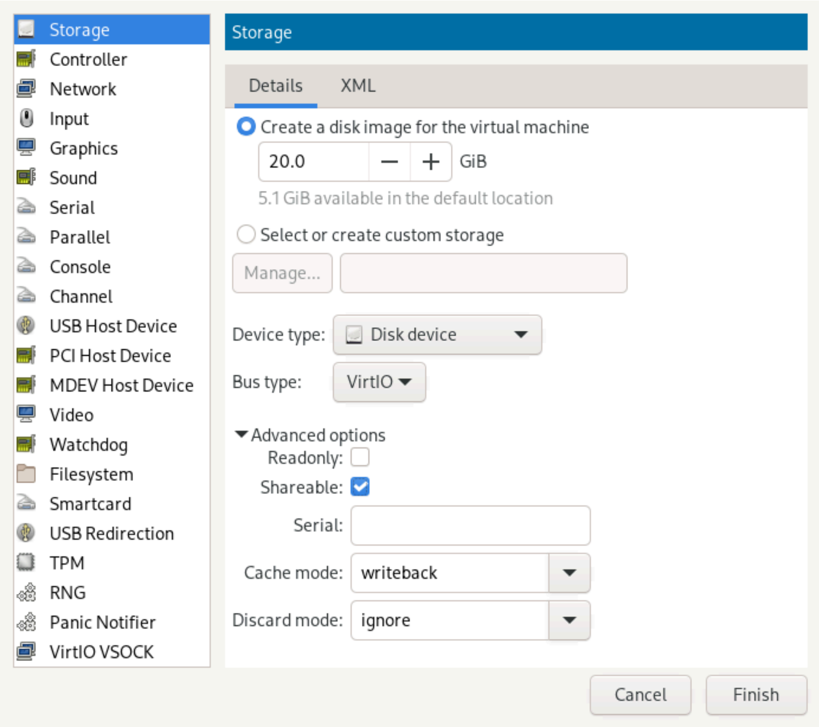
To boot a different kernel than the one on the boot device, activate *Enable direct kernel boot* and specify the paths to the alternative kernel and initrd placed on the VM Host Server file system. You can also specify kernel arguments that are passed to the loaded kernel.

13.2 Storage

This section gives you a detailed description of configuration options for storage devices. It includes both hard disks and removable media, such as USB or CD-ROM drives.

PROCEDURE 13.1: ADDING A NEW STORAGE DEVICE

1. Below the left panel, click *Add Hardware* to open the *Add New Virtual Hardware* window. There, select *Storage*.



● Create a disk image for the virtual machine

20.0 GiB

5.1 GiB available in the default location

○ Select or create custom storage

Device type: Disk device

Bus type: VirtIO

Advanced options

Readonly: □

Shareable: ☑

Serial:

Cache mode: writeback

Discard mode: ignore

FIGURE 13.9: ADD A NEW STORAGE

2. To create a `qcow2` disk image in the default location, activate *Create a disk image for the virtual machine* and specify its size in gigabytes.

To gain more control over the disk image creation, activate *Select or create custom storage* and click *Manage* to manage storage pools and images. The window *Choose Storage Volume* opens, which has almost identical functionality as the *Storage* tab described in *Section 8.2.2, “Managing storage with Virtual Machine Manager”*.

Tip: Supported storage formats

SUSE only supports the following storage formats: `raw` and `qcow2`.

3. After you create and specify the disk image file, specify the *Device type*. It can be one of the following options:

   - *Disk device*
   - *CDROM device*: does not allow using *Create a disk image for the virtual machine*.
   - *Floppy device*: does not allow using *Create a disk image for the virtual machine*.
   - *LUN Passthrough*: required to use an existing SCSI storage directly without adding it into a storage pool.

4. Select the *Bus type* for your device. The list of available options depends on the device type you selected in the previous step. The types based on *VirtIO* use paravirtualized drivers.

5. In the *Advanced options* section, select the preferred *Cache mode*. For more information on cache modes, see *Chapter 16, Disk cache modes*.

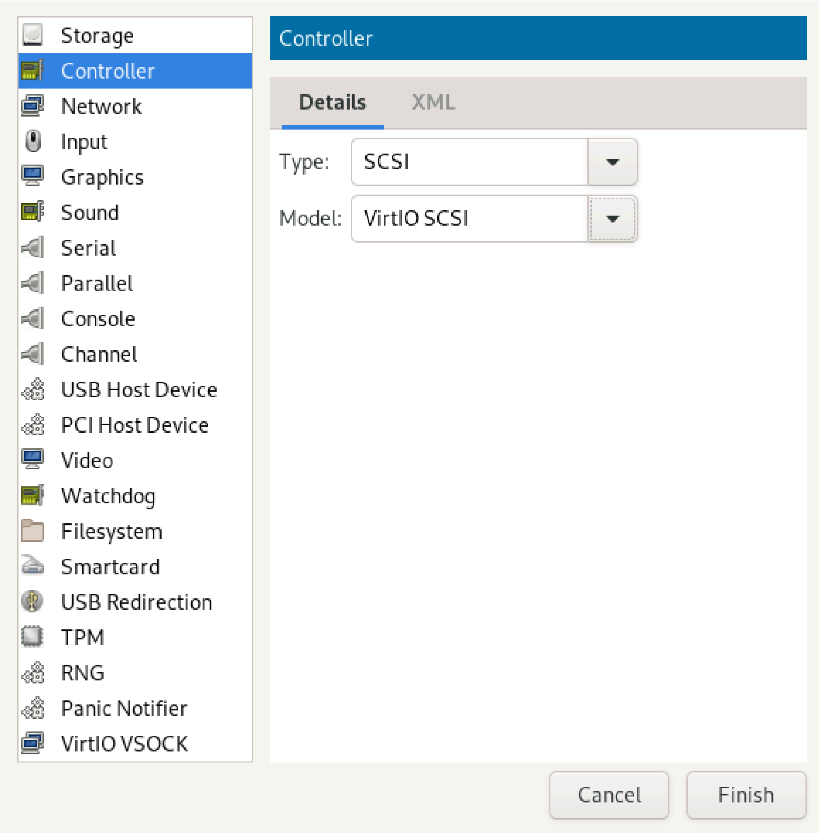
6. Confirm your settings with *Finish*. A new storage device appears in the left panel.

13.3 Controllers

This section focuses on adding and configuring new controllers.

PROCEDURE 13.2: ADDING A NEW CONTROLLER

1. Below the left panel, click *Add Hardware* to open the *Add New Virtual Hardware* window. There, select *Controller*.



Type: SCSI

Model: VirtIO SCSI

FIGURE 13.10: ADD A NEW CONTROLLER

2. Select the type of the controller. You can choose from *IDE*, *Floppy*, *SCSI*, *SATA*, *VirtIO Serial* (paravirtualized), *USB*, or *CCID* (smart card devices).

3. Optionally, for a USB or SCSI controller, select a controller model.

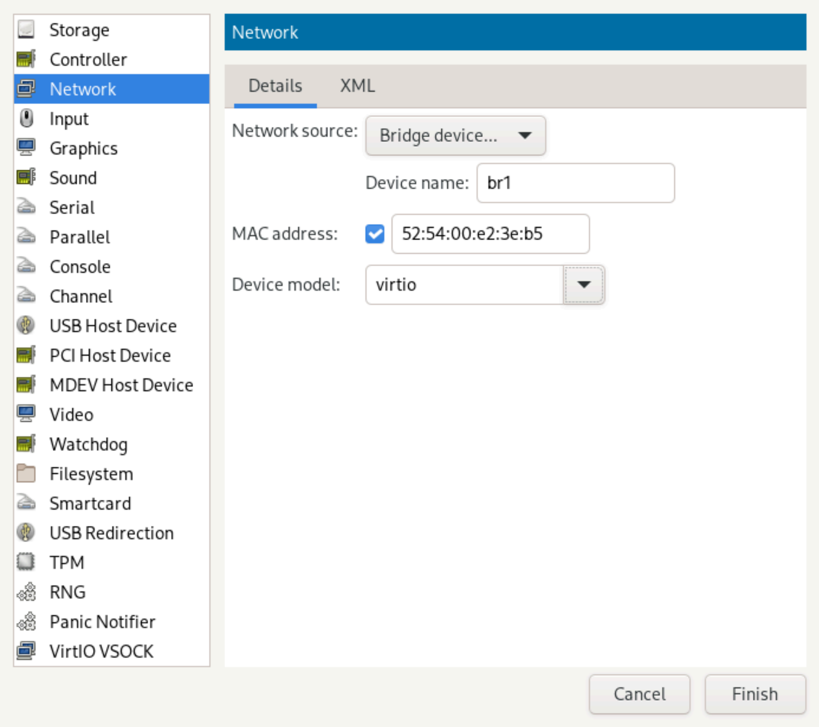
4. Confirm your settings with *Finish*. A new controller appears in the left panel.

13.4 Networking

This section describes how to add and configure new network devices.

PROCEDURE 13.3: ADDING A NEW NETWORK DEVICE

1. Below the left panel, click *Add Hardware* to open the *Add New Virtual Hardware* window. There, select *Network*.



Network source: Bridge device...

Device name: br1

MAC address: ☑ 52:54:00:e2:3e:b5

Device model: virtio

FIGURE 13.11: ADD A NEW NETWORK INTERFACE

2. From the *Network source* list, select the source for the network connection. The list includes VM Host Server's available physical network interfaces, network bridges, or network bonds. You can also assign the VM Guest to an already defined virtual network. See *Section 8.1, “Configuring networks”* for more information on setting up virtual networks with Virtual Machine Manager.

3. Specify a *MAC address* for the network device. While Virtual Machine Manager pre-fills a random value for your convenience, it is recommended to supply a MAC address appropriate for your network environment to avoid network conflicts.

4. Select a device model from the list. You can either leave the *Hypervisor default*, or specify one of *e1000*, *rtl8139*, or *virtio* models. *virtio* uses paravirtualized drivers.

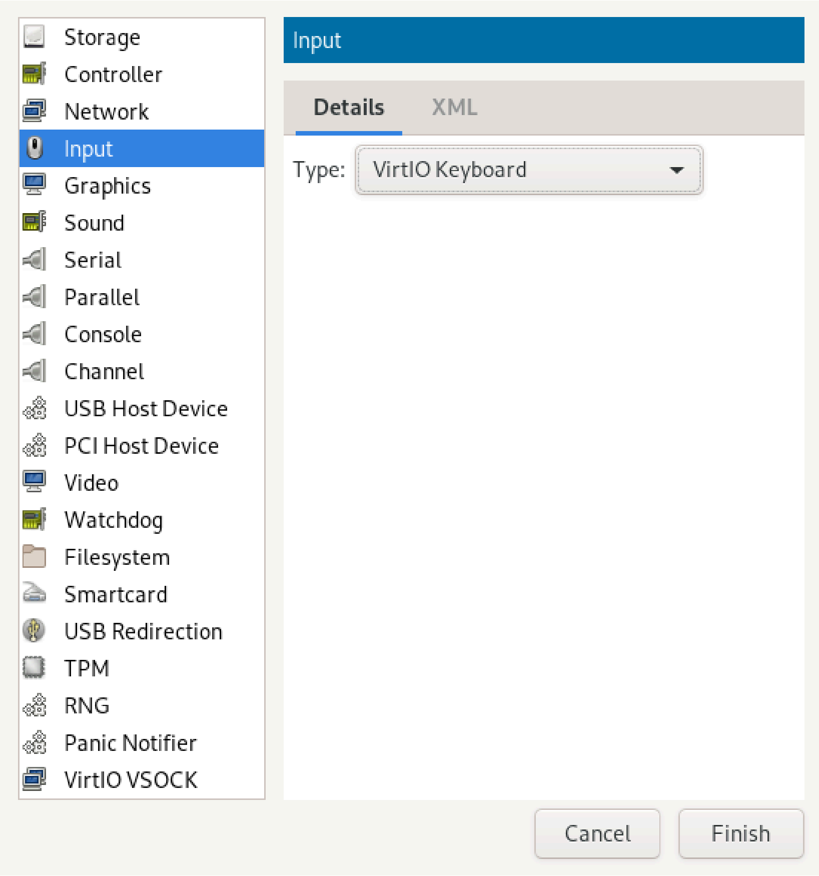
5. Confirm your settings with *Finish*. A new network device appears in the left panel.

13.5 Input devices

This section focuses on adding and configuring new input devices, such as a mouse, a keyboard or a tablet.

PROCEDURE 13.4: ADDING A NEW INPUT DEVICE

1. Below the left panel, click *Add Hardware* to open the *Add New Virtual Hardware* window. There, select *Input*.



Type: VirtIO Keyboard

FIGURE 13.12: ADD A NEW INPUT DEVICE

2. Select a device type from the list.

3. Confirm your settings with *Finish*. A new input device appears in the left panel.

Tip: Enabling seamless and synchronized mouse pointer movement

When you click within a VM Guest's console with the mouse, the pointer is captured by the console window and cannot be used outside the console unless it is explicitly released (by pressing `Alt`–`Ctrl`). To prevent the console from grabbing the key and to enable seamless pointer movement between host and guest instead, follow the instructions in *Procedure 13.4, “Adding a new input device”* to add an *EvTouch USB Graphics Tablet* to the VM Guest.

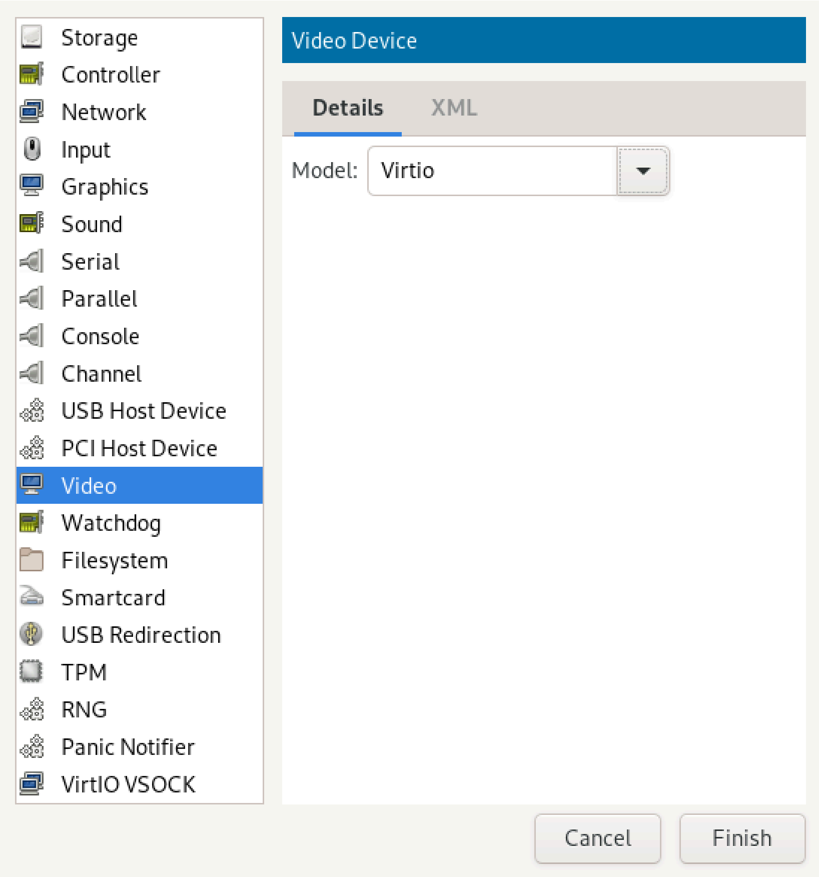
Adding a tablet has the additional advantage of synchronizing the mouse pointer movement between VM Host Server and VM Guest when using a graphical environment on the guest. With no tablet configured on the guest, you may often see two pointers with one dragging behind the other.

13.6 Video

This section describes how to add and configure new video devices.

PROCEDURE 13.5: ADDING A VIDEO DEVICE

1. Below the left panel, click *Add Hardware* to open the *Add New Virtual Hardware* window. There, select *Video*.

2. 

Model: Virtio

FIGURE 13.13: ADD A NEW VIDEO DEVICE

3. Select a model from the drop-down box.

Note: Secondary video devices

Only *QXL* and *Virtio* can be added as secondary video devices.

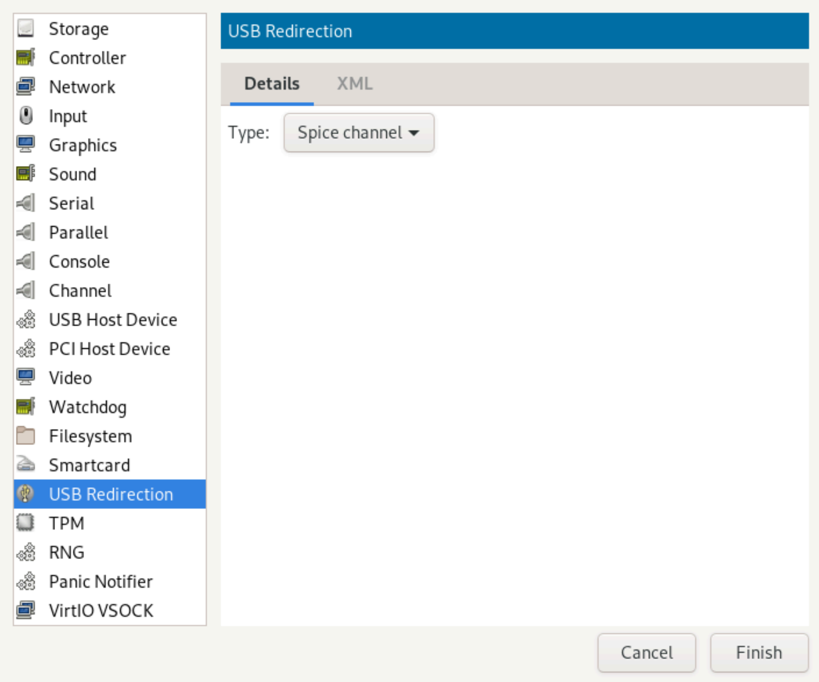
4. Confirm your settings with *Finish*. A new video device appears in the left panel.

13.7 USB redirectors

USB devices that are connected to the client machine can be redirected to the VM Guest by using *USB Redirectors*.

PROCEDURE 13.6: ADDING A USB REDIRECTOR

1. Below the left panel, click *Add Hardware* to open the *Add New Virtual Hardware* window. There, select *USB Redirection*.



Type: Spice channel

FIGURE 13.14: ADD A NEW USB REDIRECTOR

2. Select a device type from the list. Depending on your configuration, you can either select a *Spice channel* or a *TCP* redirector.

3. Confirm your settings with *Finish*. A new USB redirector appears in the left panel.

13.8 Miscellaneous

Smartcard

Smartcard functionality can be added via the *Smartcard* element. A physical USB smartcard reader can then be passed through to the VM Guest.

Watchdog

Virtual watchdog devices are also supported. They can be created via the *Watchdog* element. The model and the action of the device can be specified.

Tip: Requirements for virtual watchdog devices

QA virtual watchdog devices require a specific driver and daemon to be installed in the VM Guest. Otherwise, the virtual watchdog device does not work.

TPM

You can use the Host TPM device in the VM Guest by adding TPM functionality via the *TPM* element.

Tip: Virtual TPMs

The Host TPM can only be used in one VM Guest at a time.

13.9 Adding a CD/DVD-ROM device with Virtual Machine Manager

KVM supports CD or DVD-ROMs in VM Guest either by directly accessing a physical drive on the VM Host Server or by accessing ISO images. To create an ISO image from an existing CD or DVD, use **dd**:

```
> sudo dd if=/dev/CD_DVD_DEVICE of=my_distro.iso bs=2048
```

To add a CD/DVD-ROM device to your VM Guest, proceed as follows:

1. Double-click a VM Guest entry in the Virtual Machine Manager to open its console and switch to the *Details* view with *View* › *Details*.

2. Click *Add Hardware* and choose *Storage* in the pop-up window.

3. Change the *Device Type* to *IDE CDROM*.

4. Select *Select or create custom storage*.

    a. To assign the device to a physical medium, enter the path to the VM Host Server's CD/DVD-ROM device (for example, `/dev/cdrom`) next to *Manage*. Alternatively, use *Manage* to open a file browser and then click *Browse Local* to select the device. Assigning the device to a physical medium is only possible when the Virtual Machine Manager was started on the VM Host Server.

    b. To assign the device to an existing image, click *Manage* to choose an image from a storage pool. If the Virtual Machine Manager was started on the VM Host Server, alternatively choose an image from another location on the file system by clicking *Browse Local*. Select an image and close the file browser with *Choose Volume*.

5. Save the new virtualized device with *Finish*.

6. Reboot the VM Guest to make the new device available. For more information, see *Section 13.11, “Ejecting and changing floppy or CD/DVD-ROM media with Virtual Machine Manager”*.

13.10 Adding a floppy device with Virtual Machine Manager

Currently, KVM only supports the use of floppy disk images—using a physical floppy drive is not supported. Create a floppy disk image from an existing floppy using **dd**:

```
> sudo dd if=/dev/fd0 of=/var/lib/libvirt/images/floppy.img
```

To create an empty floppy disk image, use one of the following commands:

Raw image

```
> sudo dd if=/dev/zero of=/var/lib/libvirt/images/floppy.img bs=512 count=2880
```

FAT formatted image

```
> sudo mkfs.msdos -C /var/lib/libvirt/images/floppy.img 1440
```

To add a floppy device to your VM Guest, proceed as follows:

1. Double-click a VM Guest entry in the Virtual Machine Manager to open its console and switch to the *Details* view with *View* › *Details*.

2. Click *Add Hardware* and choose *Storage* in the pop-up window.

3. Change the *Device Type* to *Floppy Disk*.

4. Choose *Select or create custom storage* and click *Manage* to choose an existing image from a storage pool. If Virtual Machine Manager was started on the VM Host Server, alternatively choose an image from another location on the file system by clicking *Browse Local*. Select an image and close the file browser with *Choose Volume*.

5. Save the new virtualized device with *Finish*.

6. Reboot the VM Guest to make the new device available. For more information, see *Section 13.11, "Ejecting and changing floppy or CD/DVD-ROM media with Virtual Machine Manager"*.

13.11 Ejecting and changing floppy or CD/DVD-ROM media with Virtual Machine Manager

Whether you are using the VM Host Server's physical CD/DVD-ROM device or an ISO/floppy image: before you can change the media or image of an existing device in the VM Guest, you first need to `disconnect` the media from the guest.

1. Double-click a VM Guest entry in the Virtual Machine Manager to open its console and switch to the *Details* view with *View* › *Details*.

2. Choose the Floppy or CD/DVD-ROM device and "eject" the medium by clicking *Disconnect*.

3. To "insert" a new medium, click *Connect*.

    a. If using the VM Host Server's physical CD/DVD-ROM device, first change the media in the device (this may require unmounting it on the VM Host Server before it can be ejected). Then choose *CD-ROM or DVD* and select the device from the drop-down box.

    b. If you are using an ISO image, choose *ISO image Location* and select an image by clicking *Manage*. When connecting from a remote host, you may only choose images from existing storage pools.

4. Click *OK* to finish. The new media can now be accessed in the VM Guest.

13.12 Assigning a host PCI device to a VM Guest

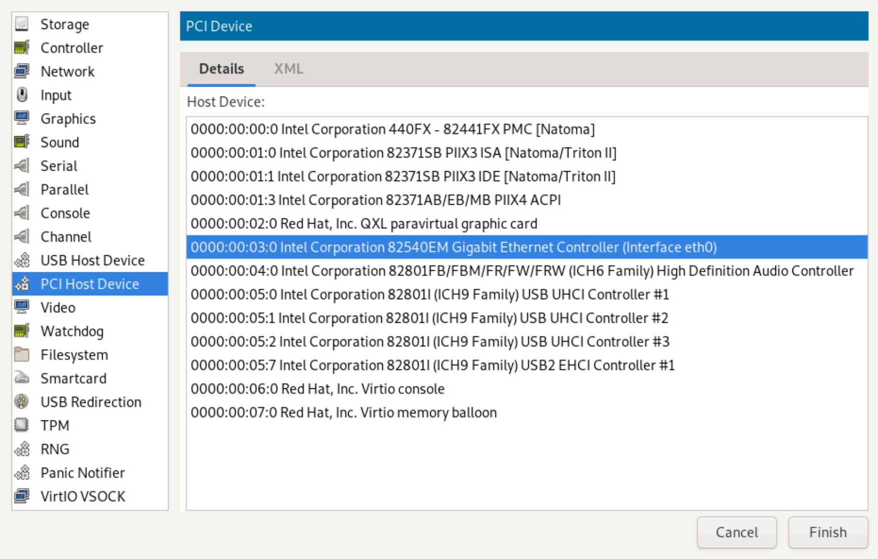
You can directly assign host-PCI devices to guests (PCI pass-through). When the PCI device is assigned to one VM Guest, it cannot be used on the host or by another VM Guest unless it is reassigned. A prerequisite for this feature is a VM Host Server configuration as described in *Important: Requirements for VFIO and SR-IOV*.

13.12.1 Adding a PCI device with Virtual Machine Manager

The following procedure describes how to assign a PCI device from the host machine to a VM Guest using Virtual Machine Manager:

1. Double-click a VM Guest entry in the Virtual Machine Manager to open its console and switch to the *Details* view with *View* › *Details*.

2. Click *Add Hardware* and choose the *PCI Host Device* category in the left panel. A list of available PCI devices appears in the right part of the window.



Host Device:

```
0000:00:00:0 Intel Corporation 440FX - 82441FX PMC [Natoma]
0000:00:01:0 Intel Corporation 82371SB PIIX3 ISA [Natoma/Triton II]
0000:00:01:1 Intel Corporation 82371SB PIIX3 IDE [Natoma/Triton II]
0000:00:01:3 Intel Corporation 82371AB/EB/MB PIIX4 ACPI
0000:00:02:0 Red Hat, Inc. QXL paravirtual graphic card
0000:00:03:0 Intel Corporation 82540EM Gigabit Ethernet Controller (Interface eth0)
0000:00:04:0 Intel Corporation 82801FB/FBM/FR/FW/FRW (ICH6 Family) High Definition Audio Controller
0000:00:05:0 Intel Corporation 82801I (ICH9 Family) USB UHCI Controller #1
0000:00:05:1 Intel Corporation 82801I (ICH9 Family) USB UHCI Controller #2
0000:00:05:2 Intel Corporation 82801I (ICH9 Family) USB UHCI Controller #3
0000:00:05:7 Intel Corporation 82801I (ICH9 Family) USB2 EHCI Controller #1
0000:00:06:0 Red Hat, Inc. Virtio console
0000:00:07:0 Red Hat, Inc. Virtio memory balloon
```

FIGURE 13.15: ADDING A PCI DEVICE

3. From the list of available PCI devices, choose the one you want to pass to the guest. Confirm with *Finish*.

Important: SLES 11 SP4 KVM guests

On a newer QEMU machine type (pc-i440fx-2.0 or higher) with SLES 11 SP4 KVM guests, the `acpiphp` module is not loaded by default in the guest. This module must be loaded to enable hotplugging of disk and network devices. To load the module manually, use the command **`modprobe acpiphp`**. It is also possible to autoload the module by adding `install acpiphp /bin/true` to the `/etc/modprobe.conf.local` file.

Important: KVM guests using QEMU Q35 machine type

KVM guests using the QEMU Q35 machine type have a PCI topology that includes a `pcie-root` controller and seven `pcie-root-port` controllers. The `pcie-root` controller does not support hotplugging. Each `pcie-root-port` controller supports hotplugging a single PCIe device. PCI controllers cannot be hotplugged, so plan accordingly and add more `pcie-root-port`s for more than seven hotplugged PCIe devices. A `pcie-to-pci-bridge` controller can be added to support hotplugging legacy PCI devices. See https://libvirt.org/pci-hotplug.html ↗ for more information about PCI topology between QEMU machine types.

13.13 Assigning a host USB device to a VM Guest

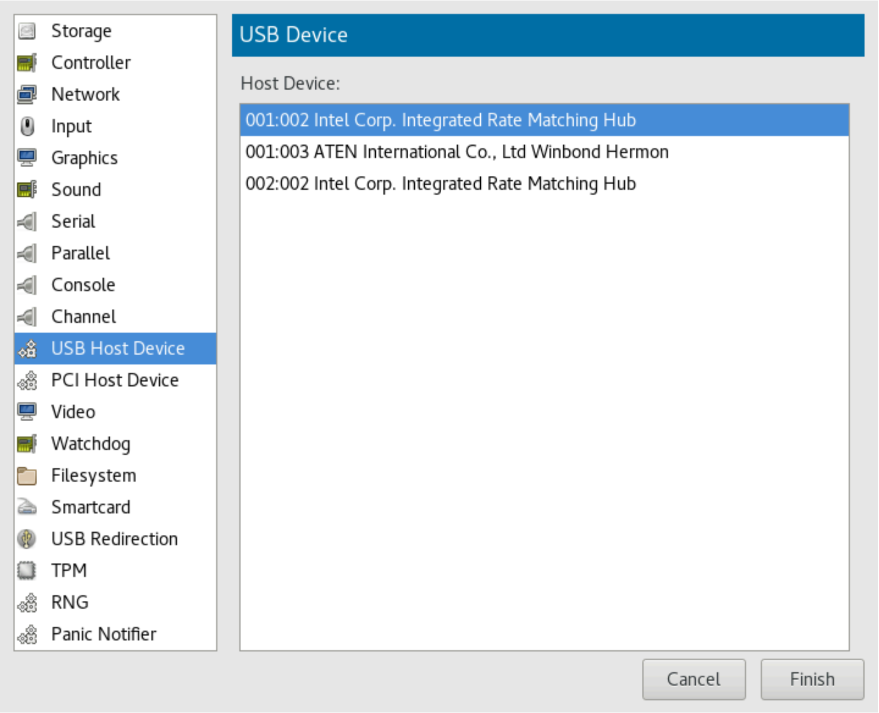
Analogous to assigning host PCI devices (see *Section 13.12, “Assigning a host PCI device to a VM Guest”*), you can directly assign host USB devices to guests. When the USB device is assigned to one VM Guest, it cannot be used on the host or by another VM Guest unless it is reassigned.

13.13.1 Adding a USB device with Virtual Machine Manager

To assign a host USB device to VM Guest using Virtual Machine Manager, follow these steps:

1. Double-click a VM Guest entry in the Virtual Machine Manager to open its console and switch to the *Details* view with *View* › *Details*.

2. Click *Add Hardware* and choose the *USB Host Device* category in the left panel. A list of available USB devices appears in the right part of the window.



001:002 Intel Corp. Integrated Rate Matching Hub
001:003 ATEN International Co., Ltd Winbond Hermon
002:002 Intel Corp. Integrated Rate Matching Hub

FIGURE 13.16: ADDING A USB DEVICE

3. From the list of available USB devices, choose the one you want to pass to the guest. Confirm with *Finish*. The new USB device appears in the left pane of the *Details* view.

Tip: USB device removal

To remove the host USB device assignment, click it in the left pane of the *Details* view and confirm with *Remove*.

14 Configuring virtual machines with **virsh**

You can use **virsh** to configure virtual machines (VM) on the command line as an alternative to using the Virtual Machine Manager. With **virsh**, you can control the state of a VM, edit the configuration of a VM or even migrate a VM to another host. The following sections describe how to manage VMs by using **virsh**.

14.1 Editing the VM configuration

The configuration of a VM is stored in an XML file in `/etc/libvirt/qemu/` and looks like this:

EXAMPLE 14.1: EXAMPLE XML CONFIGURATION FILE

```
<domain type='kvm'>
  <name>sles15</name>
  <uuid>ab953e2f-9d16-4955-bb43-1178230ee625</uuid>
  <memory unit='KiB'>2097152</memory>
  <currentMemory unit='KiB'>2097152</currentMemory>
  <vcpu placement='static'>2</vcpu>
  <os>
    <type arch='x86_64' machine='pc-q35-2.0'>hvm</type>
  </os>
  <features>...</features>
  <cpu mode='custom' match='exact' check='partial'>
    <model fallback='allow'>Skylake-Client-IBRS</model>
  </cpu>
  <clock>...</clock>
  <on_poweroff>destroy</on_poweroff>
  <on_reboot>restart</on_reboot>
  <on_crash>destroy</on_crash>
  <pm>
    <suspend-to-mem enabled='no'/>
    <suspend-to-disk enabled='no'/>
  </pm>
  <devices>
    <emulator>/usr/bin/qemu-system-x86_64</emulator>
    <disk type='file' device='disk'>...</disk>
  </devices>
  ...
</domain>
```

To edit the configuration of a VM Guest, check if it is offline:

```
> sudo virsh list --inactive
```

If your VM Guest is in this list, you can safely edit its configuration:

```
> sudo virsh edit NAME_OF_VM_GUEST
```

Before saving the changes, `virsh` validates your input against a RelaxNG schema.

14.2 Changing the machine type

When installing with the `virt-install` tool, the machine type for a VM Guest is *pc-q35* by default. The machine type is stored in the VM Guest's configuration file in the `type` element:

```
<type arch='x86_64' machine='pc-q35-2.3'>hvm</type>
```

As an example, the following procedure shows how to change this value to the machine type `q35`. The value `q35` is an Intel* chipset and includes *PCIe*, supports up to 12 USB ports, and has support for *SATA* and *IOMMU*.

PROCEDURE 14.1: CHANGING MACHINE TYPE

1. Check whether your VM Guest is inactive:

```
> sudo virsh list --inactive
Id    Name                           State
----------------------------------------------------
-     sles15                         shut off
```

2. Edit the configuration for this VM Guest:

```
> sudo virsh edit sles15
```

3. Replace the value of the `machine` attribute with `pc-q35-2.0` :

```
<type arch='x86_64' machine='pc-q35-2.0'>hvm</type>
```

4. Restart the VM Guest:

```
> sudo virsh start sles15
```

5. Check if the machine type has changed. Log in to the VM Guest and run the following command:

   ```
   > sudo dmidecode | grep Product
   Product Name: Standard PC (Q35 + ICH9, 2009)
   ```

Tip: Machine type update recommendations

Whenever the QEMU version on the host system is upgraded (for example, when upgrading the VM Host Server to a new service pack), upgrade the machine type of the VM Guests to the latest available version. To check, use the command **`qemu-system-x86_64 -M help`** on the VM Host Server.

The default machine type `pc-i440fx`, for example, is regularly updated. If your VM Guest still runs with a machine type of `pc-i440fx-1.X`, we strongly recommend an update to `pc-i440fx-2.X`. This allows taking advantage of the most recent updates and corrections in machine definitions, and ensures better future compatibility.

14.3 Configuring hypervisor features

`libvirt` automatically enables a default set of hypervisor features that are sufficient in most circumstances, but also allows enabling and disabling features as needed. As an example, Xen does not support enabling PCI pass-through by default. It must be enabled with the `passthrough` setting. Hypervisor features can be configured with **`virsh`**. Look for the `<features>` element in the VM Guest's configuration file and adjust its features as required. Continuing with the Xen pass-through example:

```
> sudo virsh edit sle15sp1
 <features>
    <xen>
      <passthrough/>
    </xen>
 </features>
```

Save your changes and restart the VM Guest.

See the *Hypervisor features* section of the libvirt *Domain XML format* manual at https://libvirt.org/formatdomain.html#elementsFeatures ↗ for more information.

14.4 Configuring CPU

Many aspects of the virtual CPUs presented to VM Guests are configurable with **virsh**. The number of current and maximum CPUs allocated to a VM Guest can be changed, as well as the model of the CPU and its feature set. The following subsections describe how to change the common CPU settings of a VM Guest.

14.4.1 Configuring the number of CPUs

The number of allocated CPUs is stored in the VM Guest's XML configuration file in /etc/libvirt/qemu/ in the vcpu element:

```
<vcpu placement='static'>1</vcpu>
```

In this example, the VM Guest has only one allocated CPU. The following procedure shows how to change the number of allocated CPUs for the VM Guest:

1. Check whether your VM Guest is inactive:

   ```
   > sudo virsh list --inactive
   Id    Name                           State
   ----------------------------------------------------
   -     sles15                         shut off
   ```

2. Edit the configuration for an existing VM Guest:

   ```
   > sudo virsh edit sles15
   ```

3. Change the number of allocated CPUs:

   ```
   <vcpu placement='static'>2</vcpu>
   ```

4. Restart the VM Guest:

   ```
   > sudo virsh start sles15
   ```

5. Check if the number of CPUs in the VM has changed.

   ```
   > sudo virsh vcpuinfo sled15
   VCPU:           0
   CPU:            N/A
   ```

```
State:          N/A
CPU time        N/A
CPU Affinity:   yy

VCPU:           1
CPU:            N/A
State:          N/A
CPU time        N/A
CPU Affinity:   yy
```

You can also change the number of CPUs while the VM Guest is running. CPUs can be hotplugged until the maximum number configured at VM Guest start is reached. Likewise, they can be hot-unplugged until the lower limit of 1 is reached. The following example shows changing the active CPU count from 2 to a predefined maximum of 4.

1. Check the current live vcpu count:

   ```
   > sudo virsh vcpucount sles15 | grep live
   maximum      live           4
   current      live           2
   ```

2. Change the current, or active, number of CPUs to 4:

   ```
   > sudo virsh setvcpus sles15 --count 4 --live
   ```

3. Check that the current live vcpu count is now 4:

   ```
   > sudo virsh vcpucount sles15 | grep live
   maximum      live           4
   current      live           4
   ```

Important: Exceeding 255 CPUs

With KVM, it is possible to define a VM Guest with more than 255 CPUs. However, additional configuration is necessary to start and run the VM Guest. The `ioapic` feature needs to be tuned and an IOMMU device needs to be added to the VM Guest. Below is an example configuration for 288 CPUs.

```
<domain>
 <vcpu placement='static'>288</vcpu>
 <features>
  <ioapic driver='qemu'/>
 </features>
 <devices>
```

```
  <iommu model='intel'>
   <driver intremap='on' eim='on'/>
  </iommu>
 </devices>
</domain>
```

14.4.2 Configuring the CPU model

The CPU model exposed to a VM Guest can often influence the workload running within it. The default CPU model is derived from a CPU mode known as `host-model`.

```
<cpu mode='host-model'/>
```

When starting a VM Guest with the CPU mode `host-model`, `libvirt` copies its model of the host CPU into the VM Guest definition. The host CPU model and features copied to the VM Guest definition can be observed in the output of the **`virsh capabilities`**.

Another interesting CPU mode is `host-passthrough`.

```
<cpu mode='host-passthrough'/>
```

When starting a VM Guest with the CPU mode `host-passthrough`, it is presented with a CPU that is exactly the same as the VM Host Server CPU. This can be useful when the VM Guest workload requires CPU features not available in `libvirt`'s simplified `host-model` CPU. The `host-passthrough` CPU mode comes with the disadvantage of reduced migration flexibility. A VM Guest with `host-passthrough` CPU mode can only be migrated to a VM Host Server with identical hardware.

When using the `host-passthrough` CPU mode, it is still possible to disable undesirable features. The following configuration presents the VM Guest with a CPU that is exactly the same as the host CPU but with the `vmx` feature disabled.

```
<cpu mode='host-passthrough'>
  <feature policy='disable' name='vmx'/>
  </cpu>
```

The `custom` CPU mode is another common mode used to define a normalized CPU that can be migrated throughout dissimilar hosts in a cluster. For example, in a cluster with hosts containing Nehalem, IvyBridge and SandyBridge CPUs, the VM Guest can be configured with a `custom` CPU mode that contains a Nehalem CPU model.

```
<cpu mode='custom' match='exact'>
  <model fallback='allow'>Nehalem</model>
  <feature policy='require' name='vme'/>
  <feature policy='require' name='ds'/>
  <feature policy='require' name='acpi'/>
  <feature policy='require' name='ss'/>
  <feature policy='require' name='ht'/>
  <feature policy='require' name='tm'/>
  <feature policy='require' name='pbe'/>
  <feature policy='require' name='dtes64'/>
  <feature policy='require' name='monitor'/>
  <feature policy='require' name='ds_cpl'/>
  <feature policy='require' name='vmx'/>
  <feature policy='require' name='est'/>
  <feature policy='require' name='tm2'/>
  <feature policy='require' name='xtpr'/>
  <feature policy='require' name='pdcm'/>
  <feature policy='require' name='dca'/>
  <feature policy='require' name='rdtscp'/>
  <feature policy='require' name='invtsc'/>
  </cpu>
```

For more information on `libvirt`'s CPU model and topology options, see the *CPU model and topology* documentation at https://libvirt.org/formatdomain.html#cpu-model-and-topology ↗.

14.5 Changing boot options

The boot menu of the VM Guest can be found in the `os` element and looks similar to this example:

```
<os>
  <type>hvm</type>
  <loader>readonly='yes' secure='no' type='rom'/>/usr/lib/xen/boot/hvmloader</loader>
  <nvram template='/usr/share/OVMF/OVMF_VARS.fd'/>/var/lib/libvirt/nvram/guest_VARS.fd</
nvram>
  <boot dev='hd'/>
  <boot dev='cdrom'/>
  <bootmenu enable='yes' timeout='3000'/>
  <smbios mode='sysinfo'/>
  <bios useserial='yes' rebootTimeout='0'/>
  </os>
```

In this example, two devices are available, `hd` and `cdrom` . The configuration also reflects the actual boot order, so the `hd` comes before the `cdrom` .

14.5.1 Changing boot order

The VM Guest's boot order is represented through the order of devices in the XML configuration file. As the devices are interchangeable, it is possible to change the boot order of the VM Guest.

1. Open the VM Guest's XML configuration.

   ```
   > sudo virsh edit sles15
   ```

2. Change the sequence of the bootable devices.

   ```
   ...
   <boot dev='cdrom'/>
   <boot dev='hd'/>
   ...
   ```

3. Check if the boot order was changed successfully by looking at the boot menu in the BIOS of the VM Guest.

14.5.2 Using direct kernel boot

Direct Kernel Boot allows you to boot from a kernel and initrd stored on the host. Set the path to both files in the `kernel` and `initrd` elements:

```
<os>
    ...
  <kernel>/root/f8-i386-vmlinuz</kernel>
  <initrd>/root/f8-i386-initrd</initrd>
    ...
<os>
```

To enable Direct Kernel Boot:

1. Open the VM Guest's XML configuration:

   ```
   > sudo virsh edit sles15
   ```

2. Inside the `os` element, add a `kernel` element and the path to the kernel file on the host:

   ```
   ...
   <kernel>/root/f8-i386-vmlinuz</kernel>
   ...
   ```

3. Add an `initrd` element and the path to the initrd file on the host:

   ```
   ...
   <initrd>/root/f8-i386-initrd</initrd>
   ...
   ```

4. Start your VM to boot from the new kernel:

   ```
   > sudo virsh start sles15
   ```

14.6 Configuring memory allocation

The amount of memory allocated for the VM Guest can also be configured with **`virsh`**. It is stored in the `memory` element and defines the maximum allocation of memory for the VM Guest at boot time. The optional `currentMemory` element defines the actual memory allocated to the VM Guest. `currentMemory` can be less than `memory`, allowing for increasing (or *ballooning*) the memory while the VM Guest is running. If `currentMemory` is omitted, it defaults to the same value as the `memory` element.

You can adjust memory settings by editing the VM Guest configuration, but be aware that changes do not take place until the next boot. The following steps demonstrate changing a VM Guest to boot with 4G of memory, but allow later expansion to 8G:

1. Open the VM Guest's XML configuration:

   ```
   > sudo virsh edit sles15
   ```

2. Search for the `memory` element and set to 8G:

   ```
   ...
   <memory unit='KiB'>8388608</memory>
   ...
   ```

3. If the `currentMemory` element does not exist, add it below the `memory` element, or change its value to 4G:

   ```
   [...]
   <memory unit='KiB'>8388608</memory>
   <currentMemory unit='KiB'>4194304</currentMemory>
   [...]
   ```

Changing the memory allocation while the VM Guest is running can be done with the **`setmem`** subcommand. The following example shows increasing the memory allocation to 8G:

1. Check VM Guest existing memory settings:

   ```
   > sudo virsh dominfo sles15 | grep memory
   Max memory:     8388608 KiB
   Used memory:    4194608 KiB
   ```

2. Change the used memory to 8G:

   ```
   > sudo virsh setmem sles15 8388608
   ```

3. Check the updated memory settings:

   ```
   > sudo virsh dominfo sles15 | grep memory
   Max memory:     8388608 KiB
   Used memory:    8388608 KiB
   ```

Important: Large memory VM Guests

VM Guests with memory requirements of 4 TB or more must either use the `host-passthrough` CPU mode, or explicitly specify the virtual CPU address size when using `host-model` or `custom` CPU modes. The default virtual CPU address size may not be sufficient for memory configurations of 4 TB or more. The following example shows how to use the VM Host Server's physical CPU address size when using the `host-model` CPU mode.

```
[...]
<cpu mode='host-model' check='partial'>
<maxphysaddr mode='passthrough'>
</cpu>
[...]
```

For more information on specifying virtual CPU address size, see the `maxphysaddr` option in the *CPU model and topology* documentation at https://libvirt.org/formatdomain.html#cpu-model-and-topology ↗.

14.7 Adding a PCI device

To assign a PCI device to VM Guest with `virsh`, follow these steps:

1. Identify the host PCI device to assign to the VM Guest. In the following example, we are assigning a DEC network card to the guest:

   ```
   > sudo lspci -nn
   [...]
   03:07.0 Ethernet controller [0200]: Digital Equipment Corporation DECchip \
   21140 [FasterNet] [1011:0009] (rev 22)
   [...]
   ```

   Write down the device ID (`03:07.0` in this case).

2. Gather detailed information about the device using `virsh nodedev-dumpxml` *`ID`*. To get the *`ID`*, replace the colon and the period in the device ID (`03:07.0`) with underscores. Prefix the result with “pci_0000_”: `pci_0000_03_07_0`.

   ```
   > sudo virsh nodedev-dumpxml pci_0000_03_07_0
   <device>
     <name>pci_0000_03_07_0</name>
     <path>/sys/devices/pci0000:00/0000:00:14.4/0000:03:07.0</path>
     <parent>pci_0000_00_14_4</parent>
     <driver>
       <name>tulip</name>
     </driver>
     <capability type='pci'>
       <domain>0</domain>
       <bus>3</bus>
       <slot>7</slot>
       <function>0</function>
       <product id='0x0009'>DECchip 21140 [FasterNet]</product>
       <vendor id='0x1011'>Digital Equipment Corporation</vendor>
       <numa node='0'/>
     </capability>
   </device>
   ```

   Write down the values for domain, bus and function (see the previous XML code printed in bold).

3. Detach the device from the host system before attaching it to the VM Guest:

   ```
   > sudo virsh nodedev-detach pci_0000_03_07_0
     Device pci_0000_03_07_0 detached
   ```

Tip: Multi-function PCI devices

When using a multi-function PCI device that does not support FLR (function level reset) or PM (power management) reset, you need to detach all its functions from the VM Host Server. The whole device must be reset for security reasons. `libvirt` refuses to assign the device if one of its functions is still in use by the VM Host Server or another VM Guest.

4. Convert the domain, bus, slot, and function value from decimal to hexadecimal. In our example, domain = 0, bus = 3, slot = 7, and function = 0. Ensure that the values are inserted in the right order:

```
> printf "<address domain='0x%x' bus='0x%x' slot='0x%x' function='0x%x'/>\n" 0 3 7 0
```

This results in:

```
<address domain='0x0' bus='0x3' slot='0x7' function='0x0'/>
```

5. Run **`virsh edit`** on your domain, and add the following device entry in the `<devices>` section using the result from the previous step:

```
<hostdev mode='subsystem' type='pci' managed='yes'>
  <source>
    <address domain='0x0' bus='0x03' slot='0x07' function='0x0'/>
  </source>
</hostdev>
```

Tip: managed compared to unmanaged

`libvirt` recognizes two modes for handling PCI devices: they can be `managed` or `unmanaged`. In the managed case, `libvirt` handles all details of unbinding the device from the existing driver if needed, resetting the device, binding it to `vfio-pci` before starting the domain, etc. When the domain is terminated or the device is removed from the domain, `libvirt` unbinds from `vfio-pci` and rebinds to the original driver in the case of a managed device. If the device is unmanaged, the user must ensure that all these management aspects of the device are done before assigning it to a domain, and after the device is no longer used by the domain.

In the example above, the `managed='yes'` option means that the device is managed. To switch the device mode to unmanaged, set `managed='no'` in the listing above. If you do so, you need to take care of the related driver with the **`virsh nodedev-detach`** and **`virsh nodedev-reattach`** commands. Before starting the VM Guest, you need to detach the device from the host by running **`virsh nodedev-detach pci_0000_03_07_0`**. In case the VM Guest is not running, you can make the device available for the host by running **`virsh nodedev-reattach pci_0000_03_07_0`**.

6. Shut down the VM Guest and disable SELinux if it is running on the host.

```
> sudo setsebool -P virt_use_sysfs 1
```

7. Start your VM Guest to make the assigned PCI device available:

```
> sudo virsh start sles15
```

Important: SLES11 SP4 KVM guests

On a newer QEMU machine type (pc-i440fx-2.0 or higher) with SLES 11 SP4 KVM guests, the `acpiphp` module is not loaded by default in the guest. This module must be loaded to enable hotplugging of disk and network devices. To load the module manually, use the command **`modprobe acpiphp`**. It is also possible to autoload the module by adding `install acpiphp /bin/true` to the `/etc/modprobe.conf.local` file.

Important: KVM guests using QEMU Q35 machine type

KVM guests using the QEMU Q35 machine type have a PCI topology that includes a `pcie-root` controller and seven `pcie-root-port` controllers. The `pcie-root` controller does not support hotplugging. Each `pcie-root-port` controller supports hotplugging a single PCIe device. PCI controllers cannot be hotplugged, so plan accordingly and add more `pcie-root-port`s to hotplug more than seven PCIe devices. A `pcie-to-pci-bridge` controller can be added to support hotplugging legacy PCI devices. See https://libvirt.org/pci-hotplug.html ↗ for more information about PCI topology between QEMU machine types.

14.7.1 PCI Pass-Through for IBM Z

To support IBM Z, QEMU extended PCI representation by allowing the user to configure extra attributes. Two more attributes— `uid` and `fid` —were added to the `<zpci/>` `libvirt` specification. `uid` represents user-defined identifier, while `fid` represents PCI function identifier. These attributes are optional and if you do not specify them, they are automatically generated with non-conflicting values.

To include zPCI attribute in your domain specification, use the following example definition:

```
<controller type='pci' index='0' model='pci-root'/>
<controller type='pci' index='1' model='pci-bridge'>
  <model name='pci-bridge'/>
  <target chassisNr='1'/>
  <address type='pci' domain='0x0000' bus='0x00' slot='0x01' function='0x0'>
    <zpci uid='0x0001' fid='0x00000000'/>
  </address>
</controller>
<interface type='bridge'>
  <source bridge='virbr0'/>
  <model type='virtio'/>
  <address type='pci' domain='0x0000' bus='0x01' slot='0x01' function='0x0'>
    <zpci uid='0x0007' fid='0x00000003'/>
  </address>
</interface>
```

14.8 Adding a USB device

To assign a USB device to VM Guest using **`virsh`**, follow these steps:

1. Identify the host USB device to assign to the VM Guest:

   ```
   > sudo lsusb
   [...]
   Bus 001 Device 003: ID 0557:2221 ATEN International Co., Ltd Winbond Hermon
   [...]
   ```

   Write down the vendor and product IDs. In our example, the vendor ID is `0557` and the product ID is `2221`.

2. Run **`virsh edit`** on your domain, and add the following device entry in the `<devices>` section using the values from the previous step:

```
<hostdev mode='subsystem' type='usb'>
  <source startupPolicy='optional'>
   <vendor id='0557'/>
   <product id='2221'/>
  </source>
</hostdev>
```

Tip: Vendor/product or device's address

Instead of defining the host device with `<vendor/>` and `<product/>` IDs, you can use the `<address/>` element as described for host PCI devices in *Section 14.7, “Adding a PCI device”*.

3. Shut down the VM Guest and disable SELinux if it is running on the host:

```
> sudo setsebool -P virt_use_sysfs 1
```

4. Start your VM Guest to make the assigned PCI device available:

```
> sudo virsh start sles15
```

14.9 Adding SR-IOV devices

Single Root I/O Virtualization (*SR-IOV*) capable *PCIe* devices can replicate their resources, so they appear as multiple devices. Each of these “pseudo-devices” can be assigned to a VM Guest.

SR-IOV is an industry specification that was created by the Peripheral Component Interconnect Special Interest Group (PCI-SIG) consortium. It introduces physical functions (PF) and virtual functions (VF). PFs are full *PCIe* functions used to manage and configure the device. PFs also can move data. VFs lack the configuration and management part—they only can move data and a reduced set of configuration functions. As VFs do not have all *PCIe* functions, the host operating system or the *Hypervisor* must support *SR-IOV* to access and initialize VFs. The theoretical maximum for VFs is 256 per device (consequently the maximum for a dual-port Ethernet card would be 512). In practice, this maximum is much lower, since each VF consumes resources.

14.9.1 Requirements

The following requirements must be met to use *SR-IOV*:

- An *SR-IOV*-capable network card (as of , only network cards support *SR-IOV*)
- An AMD64/Intel 64 host supporting hardware virtualization (AMD-V or Intel VT-x)
- A chipset that supports device assignment (AMD-Vi or Intel *VT-d*)
- `libvirt` 0.9.10 or better
- *SR-IOV* drivers must be loaded and configured on the host system
- A host configuration that meets the requirements listed at *Important: Requirements for VFIO and SR-IOV*
- A list of the PCI addresses of the VFs assigned to VM Guests

Tip: Checking if a device is SR-IOV-capable

The information whether a device is SR-IOV-capable can be obtained from its PCI descriptor by running **`lspci`**. A device that supports *SR-IOV* reports a capability similar to the following:

```
Capabilities: [160 v1] Single Root I/O Virtualization (SR-IOV)
```

Note: Adding an SR-IOV device at VM Guest creation

Before adding an SR-IOV device to a VM Guest when initially setting it up, the VM Host Server already needs to be configured as described in *Section 14.9.2, “Loading and configuring the SR-IOV host drivers”*.

14.9.2 Loading and configuring the SR-IOV host drivers

To access and initialize VFs, an SR-IOV-capable driver needs to be loaded on the host system.

1. Before loading the driver, make sure the card is properly detected by running **`lspci`**. The following example shows the **`lspci`** output for the dual-port Intel 82576NS network card:

```
> sudo /sbin/lspci | grep 82576
```

```
01:00.0 Ethernet controller: Intel Corporation 82576NS Gigabit Network Connection
 (rev 01)
01:00.1 Ethernet controller: Intel Corporation 82576NS Gigabit Network Connection
 (rev 01)
04:00.0 Ethernet controller: Intel Corporation 82576NS Gigabit Network Connection
 (rev 01)
04:00.1 Ethernet controller: Intel Corporation 82576NS Gigabit Network Connection
 (rev 01)
```

In case the card is not detected, the hardware virtualization support in the BIOS/EFI has probably not been enabled. To check if hardware virtualization support is enabled, look at the settings in the host's BIOS.

2. Check whether the *SR-IOV* driver is already loaded by running **`lsmod`**. In the following example, a check for the igb driver (for the Intel 82576NS network card) returns a result. That means the driver is already loaded. If the command returns nothing, the driver is not loaded.

```
> sudo /sbin/lsmod | egrep "^igb "
igb                    185649  0
```

3. Skip the following step if the driver is already loaded. If the *SR-IOV* driver is not yet loaded, the non-*SR-IOV* driver needs to be removed first, before loading the new driver. Use **`rmmod`** to unload a driver. The following example unloads the non-*SR-IOV* driver for the Intel 82576NS network card:

```
> sudo /sbin/rmmod igbvf
```

4. Load the *SR-IOV* driver subsequently using the **`modprobe`** command—the VF parameter (`max_vfs`) is mandatory:

```
> sudo /sbin/modprobe igb max_vfs=8
```

As an alternative, you can also load the driver via SYSFS:

1. Find the PCI ID of the physical NIC by listing Ethernet devices:

```
> sudo lspci | grep Eth
06:00.0 Ethernet controller: Emulex Corporation OneConnect NIC (Skyhawk) (rev 10)
06:00.1 Ethernet controller: Emulex Corporation OneConnect NIC (Skyhawk) (rev 10)
```

2. To enable VFs, echo the number of desired VFs to load to the `sriov_numvfs` parameter:

```
> sudo echo 1 > /sys/bus/pci/devices/0000:06:00.1/sriov_numvfs
```

3. Verify that the VF NIC was loaded:

```
> sudo lspci | grep Eth
06:00.0 Ethernet controller: Emulex Corporation OneConnect NIC (Skyhawk) (rev 10)
06:00.1 Ethernet controller: Emulex Corporation OneConnect NIC (Skyhawk) (rev 10)
06:08.0 Ethernet controller: Emulex Corporation OneConnect NIC (Skyhawk) (rev 10)
```

4. Obtain the maximum number of VFs available:

```
> sudo lspci -vvv -s 06:00.1 | grep 'Initial VFs'
                       Initial VFs: 32, Total VFs: 32, Number of VFs: 0,
Function Dependency Link: 01
```

5. Create a `/etc/systemd/system/before.service` file which loads VF via SYSFS on boot:

```
[Unit]
Before=
[Service]
Type=oneshot
RemainAfterExit=true
ExecStart=/bin/bash -c "echo 1 > /sys/bus/pci/devices/0000:06:00.1/sriov_numvfs"
# beware, executable is run directly, not through a shell, check the man pages
# systemd.service and systemd.unit for full syntax
[Install]
# target in which to start the service
WantedBy=multi-user.target
#WantedBy=graphical.target
```

6. Before starting the VM, it is required to create another service file (`after-local.service`) pointing to the `/etc/init.d/after.local` script that detaches the NIC. Otherwise the VM would fail to start:

```
[Unit]
Description=/etc/init.d/after.local Compatibility
After=libvirtd.service
Requires=libvirtd.service
[Service]
Type=oneshot
ExecStart=/etc/init.d/after.local
RemainAfterExit=true

[Install]
WantedBy=multi-user.target
```

7. Copy it to `/etc/systemd/system`.

```
#! /bin/sh
# ...
virsh nodedev-detach pci_0000_06_08_0
```

Save it as `/etc/init.d/after.local`.

8. Reboot the machine and check if the SR-IOV driver is loaded by re-running the **`lspci`** command from the first step of this procedure. If the SR-IOV driver was loaded successfully you should see additional lines for the VFs:

```
01:00.0 Ethernet controller: Intel Corporation 82576NS Gigabit Network Connection
 (rev 01)
01:00.1 Ethernet controller: Intel Corporation 82576NS Gigabit Network Connection
 (rev 01)
01:10.0 Ethernet controller: Intel Corporation 82576 Virtual Function (rev 01)
01:10.1 Ethernet controller: Intel Corporation 82576 Virtual Function (rev 01)
01:10.2 Ethernet controller: Intel Corporation 82576 Virtual Function (rev 01)
[...]
04:00.0 Ethernet controller: Intel Corporation 82576NS Gigabit Network Connection
 (rev 01)
04:00.1 Ethernet controller: Intel Corporation 82576NS Gigabit Network Connection
 (rev 01)
04:10.0 Ethernet controller: Intel Corporation 82576 Virtual Function (rev 01)
04:10.1 Ethernet controller: Intel Corporation 82576 Virtual Function (rev 01)
04:10.2 Ethernet controller: Intel Corporation 82576 Virtual Function (rev 01)
[...]
```

14.9.3 Adding a VF network device to a VM Guest

When the *SR-IOV* hardware is properly set up on the VM Host Server, you can add VFs to VM Guests. To do so, you need to collect specific data first.

PROCEDURE 14.2: ADDING A VF NETWORK DEVICE TO AN EXISTING VM GUEST

The following procedure uses example data. Replace it with appropriate data from your setup.

1. Use the **`virsh nodedev-list`** command to get the PCI address of the VF you want to assign and its corresponding PF. Numerical values from the **`lspci`** output shown in *Section 14.9.2, “Loading and configuring the SR-IOV host drivers”* (for example `01:00.0` or `04:00.1`) are transformed by adding the prefix `pci_0000_` and by replacing colons

and dots with underscores. So a PCI ID listed as `04:00.0` by **`lspci`** is listed as `pci_0000_04_00_0` by virsh. The following example lists the PCI IDs for the second port of the Intel 82576NS network card:

```
> sudo virsh nodedev-list | grep 0000_04_
pci_0000_04_00_0
pci_0000_04_00_1
pci_0000_04_10_0
pci_0000_04_10_1
pci_0000_04_10_2
pci_0000_04_10_3
pci_0000_04_10_4
pci_0000_04_10_5
pci_0000_04_10_6
pci_0000_04_10_7
pci_0000_04_11_0
pci_0000_04_11_1
pci_0000_04_11_2
pci_0000_04_11_3
pci_0000_04_11_4
pci_0000_04_11_5
```

The first two entries represent the **PFs**, whereas the other entries represent the VFs.

2. Run the following **`virsh nodedev-dumpxml`** command on the PCI ID of the VF you want to add:

```
> sudo virsh nodedev-dumpxml pci_0000_04_10_0
<device>
  <name>pci_0000_04_10_0</name>
  <parent>pci_0000_00_02_0</parent>
  <capability type='pci'>
    <domain>0</domain>
    <bus>4</bus>
    <slot>16</slot>
    <function>0</function>
    <product id='0x10ca'>82576 Virtual Function</product>
    <vendor id='0x8086'>Intel Corporation</vendor>
    <capability type='phys_function'>
      <address domain='0x0000' bus='0x04' slot='0x00' function='0x0'/>
    </capability>
  </capability>
</device>
```

The following data is needed for the next step:

- `<domain>0</domain>`
- `<bus>4</bus>`
- `<slot>16</slot>`
- `<function>0</function>`

3. Create a temporary XML file (for example `/tmp/vf-interface.xml` containing the data necessary to add a VF network device to an existing VM Guest. The minimal content of the file needs to look like the following:

```
<interface type='hostdev'>❶
 <source>
  <address type='pci' domain='0' bus='11' slot='16' function='0'2/>❷
 </source>
</interface>
```

❶ VFs do not get a fixed MAC address; it changes every time the host reboots. When adding network devices the “traditional” way with `hostdev`, it would require to reconfigure the VM Guest's network device after each reboot of the host, because of the MAC address change. To avoid this kind of problem, `libvirt` introduced the `hostdev` value, which sets up network-specific data *before* assigning the device.

❷ Specify the data you acquired in the previous step here.

4. In case a device is already attached to the host, it cannot be attached to a VM Guest. To make it available for guests, detach it from the host first:

```
> sudo virsh nodedev-detach pci_0000_04_10_0
```

5. Add the VF interface to an existing VM Guest:

```
> sudo virsh attach-device GUEST /tmp/vf-interface.xml --OPTION
```

`GUEST` needs to be replaced by the domain name, ID or UUID of the VM Guest. --*`OPTION`* can be one of the following:

`--persistent`

This option always adds the device to the domain's persistent XML. If the domain is running, the device is hotplugged.

`--config`

This option affects the persistent XML only, even if the domain is running. The device appears in the VM Guest on next boot.

`--live`

This option affects a running domain only. If the domain is inactive, the operation fails. The device is not persisted in the XML and becomes available in the VM Guest on next boot.

`--current`

This option affects the current state of the domain. If the domain is inactive, the device is added to the persistent XML and becomes available on next boot. If the domain is active, the device is hotplugged but not added to the persistent XML.

6. To detach a VF interface, use the **`virsh detach-device`** command, which also takes the options listed above.

14.9.4 Dynamic allocation of VFs from a pool

If you define the PCI address of a VF into a VM Guest's configuration statically as described in *Section 14.9.3, “Adding a VF network device to a VM Guest”*, it is hard to migrate such guest to another host. The host must have identical hardware in the same location on the PCI bus, or the VM Guest configuration must be modified before each start.

Another approach is to create a `libvirt` network with a device pool that contains all the VFs of an *SR-IOV* device. The VM Guest then references this network, and each time it is started, a single VF is dynamically allocated to it. When the VM Guest is stopped, the VF is returned to the pool, available for another guest.

14.9.4.1 Defining network with pool of VFs on VM Host Server

The following example of network definition creates a pool of all VFs for the *SR-IOV* device with its physical function (PF) at the network interface `eth0` on the host:

```
<network>
  <name>passthrough</name>
    <forward mode='hostdev' managed='yes'>
      <pf dev='eth0'/>
    </forward>
  </network>
```

To use this network on the host, save the above code to a file, for example `/tmp/passthrough.xml`, and execute the following commands. Remember to replace `eth0` with the real network interface name of your *SR-IOV* device's PF:

```
> sudo virsh net-define /tmp/passthrough.xml
> sudo virsh net-autostart passthrough
> sudo virsh net-start passthrough
```

14.9.4.2 Configuring VM Guests to use VF from the pool

The following example of VM Guest device interface definition uses a VF of the *SR-IOV* device from the pool created in *Section 14.9.4.1, “Defining network with pool of VFs on VM Host Server”*. `libvirt` automatically derives the list of all VFs associated with that PF the first time the guest is started.

```
<interface type='network'>
  <source network='passthrough'>
</interface>
```

After the first VM Guest starts that uses the network with the pool of VFs, verify the list of associated VFs. Do so by running **`virsh net-dumpxml passthrough`** on the host.

```
<network connections='1'>
  <name>passthrough</name>
  <uuid>a6a26429-d483-d4ed-3465-4436ac786437</uuid>
  <forward mode='hostdev' managed='yes'>
    <pf dev='eth0'/>
    <address type='pci' domain='0x0000' bus='0x02' slot='0x10' function='0x1'/>
    <address type='pci' domain='0x0000' bus='0x02' slot='0x10' function='0x3'/>
    <address type='pci' domain='0x0000' bus='0x02' slot='0x10' function='0x5'/>
    <address type='pci' domain='0x0000' bus='0x02' slot='0x10' function='0x7'/>
    <address type='pci' domain='0x0000' bus='0x02' slot='0x11' function='0x1'/>
    <address type='pci' domain='0x0000' bus='0x02' slot='0x11' function='0x3'/>
    <address type='pci' domain='0x0000' bus='0x02' slot='0x11' function='0x5'/>
  </forward>
  </network>
```

14.10 Listing attached devices

Although there is no mechanism in **virsh** to list all VM Host Server's devices that have already been attached to its VM Guests, you can list all devices attached to a specific VM Guest by running the following command:

```
virsh dumpxml VMGUEST_NAME | xpath -e /domain/devices/hostdev
```

For example:

```
> sudo virsh dumpxml sles12 | -e xpath /domain/devices/hostdev
Found 2 nodes:
-- NODE --
<hostdev mode="subsystem" type="pci" managed="yes">
  <driver name="xen" />
  <source>
    <address domain="0x0000" bus="0x0a" slot="0x10" function="0x1" />
  </source>
  <address type="pci" domain="0x0000" bus="0x00" slot="0x0a" function="0x0" />
  </hostdev>
-- NODE --
<hostdev mode="subsystem" type="pci" managed="yes">
  <driver name="xen" />
  <source>
    <address domain="0x0000" bus="0x0a" slot="0x10" function="0x2" />
  </source>
  <address type="pci" domain="0x0000" bus="0x00" slot="0x0b" function="0x0" />
</hostdev>
```

Tip: Listing SR-IOV devices attached via <interface type='hostdev'>

For SR-IOV devices that are attached to the VM Host Server via `<interface type='hostdev'>`, you need to use a different XPath query:

```
virsh dumpxml VMGUEST_NAME | xpath -e /domain/devices/interface/@type
```

14.11 Configuring storage devices

Storage devices are defined within the `disk` element. The usual `disk` element supports several attributes. The following two attributes are the most important:

- The `type` attribute describes the source of the virtual disk device. Valid values are `file` , `block` , `dir` , `network` , or `volume` .
- The `device` attribute shows how the disk is exposed to the VM Guest OS. As an example, possible values can include `floppy` , `disk` , `cdrom` , and others.

The following child elements are the most important:

- `driver` contains the driver and the bus. These are used by the VM Guest to work with the new disk device.
- The `target` element contains the device name under which the new disk is shown in the VM Guest. It also contains the optional bus attribute, which defines the type of bus on which the new disk should operate.

The following procedure shows how to add storage devices to the VM Guest:

1. Edit the configuration for an existing VM Guest:

   ```
   > sudo virsh edit sles15
   ```

2. Add a `disk` element inside the `disk` element together with the attributes `type` and `device`:

   ```
   <disk type='file' device='disk'>
   ```

3. Specify a `driver` element and use the default values:

   ```
   <driver name='qemu' type='qcow2'/>
   ```

4. Create a disk image as a source for the new virtual disk device:

   ```
   > sudo qemu-img create -f qcow2 /var/lib/libvirt/images/sles15.qcow2 32G
   ```

5. Add the path for the disk source:

   ```
   <source file='/var/lib/libvirt/images/sles15.qcow2'/>
   ```

6. Define the target device name in the VM Guest and the bus on which the disk should work:

   ```
   <target dev='vda' bus='virtio'/>
   ```

7. Restart your VM:

   ```
   > sudo virsh start sles15
   ```

Your new storage device should be available in the VM Guest OS.

14.12 Configuring controller devices

libvirt manages controllers automatically based on the type of virtual devices used by the VM Guest. If the VM Guest contains PCI and SCSI devices, PCI and SCSI controllers are created and managed automatically. **libvirt** also models controllers that are hypervisor-specific, for example, a `virtio-serial` controller for KVM VM Guests or a `xenbus` controller for Xen VM Guests. Although the default controllers and their configuration are generally fine, there may be use cases where controllers or their attributes need to be adjusted manually. For example, a virtio-serial controller may need more ports, or a xenbus controller may need more memory or more virtual interrupts.

The xenbus controller is unique in that it serves as the controller for all Xen paravirtual devices. If a VM Guest has many disk and/or network devices, the controller may need more memory. Xen's `max_grant_frames` attribute sets how many grant frames, or blocks of shared memory, are allocated to the `xenbus` controller for each VM Guest.

The default of 32 is enough in most circumstances, but a VM Guest with numerous I/O devices and an I/O-intensive workload may experience performance issues because of grant frame exhaustion. The **xen-diag** can check the current and maximum `max_grant_frames` values for dom0 and your VM Guests. The VM Guests must be running:

```
> sudo virsh list
 Id   Name               State
--------------------------------
 0    Domain-0           running
 3    sle15sp1           running

 > sudo xen-diag gnttab_query_size 0
domid=0: nr_frames=1, max_nr_frames=256

> sudo xen-diag gnttab_query_size 3
```

```
domid=3: nr_frames=3, max_nr_frames=32
```

The `sle15sp1` guest is using only three frames out of 32. If you are seeing performance issues, and log entries that point to insufficient frames, increase the value with **`virsh`**. Look for the `<controller type='xenbus'>` line in the guest's configuration file and add the `maxGrantFrames` control element:

```
> sudo virsh edit sle15sp1
 <controller type='xenbus' index='0' maxGrantFrames='40'/>
```

Save your changes and restart the guest. Now it should show your change:

```
> sudo xen-diag gnttab_query_size 3
domid=3: nr_frames=3, max_nr_frames=40
```

Similar to maxGrantFrames, the xenbus controller also supports `maxEventChannels`. Event channels are like paravirtual interrupts, and in conjunction with grant frames, form a data transfer mechanism for paravirtual drivers. They are also used for inter-processor interrupts. VM Guests with a large number of vCPUs and/or many paravirtual devices may need to increase the maximum default value of 1023. maxEventChannels can be changed similarly to maxGrantFrames:

```
> sudo virsh edit sle15sp1
 <controller type='xenbus' index='0' maxGrantFrames='128' maxEventChannels='2047'/>
```

See the *Controllers* section of the libvirt *Domain XML format* manual at https://libvirt.org/formatdomain.html#elementsControllers for more information.

14.13 Configuring video devices

When using the Virtual Machine Manager, only the Video device model can be defined. The amount of allocated VRAM or 2D/3D acceleration can only be changed in the XML configuration.

14.13.1 Changing the amount of allocated VRAM

1. Edit the configuration for an existing VM Guest:

   ```
   > sudo virsh edit sles15
   ```

2. Change the size of the allocated VRAM:

```
<video>
<model type='vga' vram='65535' heads='1'>
...
</model>
</video>
```

3. Check if the amount of VRAM in the VM has changed by looking at the amount in the Virtual Machine Manager.

14.13.2 Changing the state of 2D/3D acceleration

1. Edit the configuration for an existing VM Guest:

```
> sudo virsh edit sles15
```

2. To enable/disable 2D/3D acceleration, change the value of `accel3d` and `accel2d` accordingly:

```
<video>
 <model>
  <acceleration accel3d='yes' accel2d='no'>
 </model>
</video>
```

Tip: Enabling 2D/3D acceleration

Only `virtio` and `vbox` video devices are capable of 2D/3D acceleration. You cannot enable it on other video devices.

14.14 Configuring network devices

This section describes how to configure specific aspects of virtual network devices by using **`virsh`**.

Find more details about `libvirt` network interface specification in https://libvirt.org/formatdomain.html#elementsDriverBackendOptions ↗.

14.14.1 Scaling network performance with multiqueue virtio-net

The multiqueue virtio-net feature scales the network performance by allowing the VM Guest's virtual CPUs to transfer packets in parallel. Refer to *Section 32.3.3, “Scaling network performance with multiqueue virtio-net”* for more general information.

To enable multiqueue virtio-net for a specific VM Guest, edit its XML configuration as described in *Section 14.1, “Editing the VM configuration”* and modify its network interface as follows:

```
<interface type='network'>
 [...]
 <model type='virtio'/>
 <driver name='vhost' queues='NUMBER_OF_QUEUES'/>
</interface>
```

14.15 Using macvtap to share VM Host Server network interfaces

Macvtap provides direct attachment of a VM Guest virtual interface to a host network interface. The macvtap-based interface extends the VM Host Server network interface and has its own MAC address on the same Ethernet segment. Typically, this is used to make both the VM Guest and the VM Host Server show up directly on the switch that the VM Host Server is connected to.

Note: Macvtap cannot be used with a Linux bridge

Macvtap cannot be used with network interfaces already connected to a Linux bridge. Before attempting to create the macvtap interface, remove the interface from the bridge.

Note: VM Guest to VM Host Server communication with macvtap

When using macvtap, a VM Guest can communicate with other VM Guests, and with other external hosts on the network. But it cannot communicate with the VM Host Server on which the VM Guest runs. This is the defined behavior of macvtap, because of the way the VM Host Server's physical Ethernet is attached to the macvtap bridge. Traffic from the VM Guest into that bridge that is forwarded to the physical interface cannot be bounced back up to the VM Host Server's IP stack. Similarly, traffic from the VM Host Server's IP stack that is sent to the physical interface cannot be bounced back up to the macvtap bridge for forwarding to the VM Guest.

Virtual network interfaces based on macvtap are supported by libvirt by specifying an interface type of `direct`. For example:

```
<interface type='direct'>
   <mac address='aa:bb:cc:dd:ee:ff'/>
   <source dev='eth0' mode='bridge'/>
   <model type='virtio'/>
   </interface>
```

The operation mode of the macvtap device can be controlled with the `mode` attribute. The following list shows its possible values and a description for each:

- `vepa`: all VM Guest packets are sent to an external bridge. Packets whose destination is a VM Guest on the same VM Host Server as where the packet originates from are sent back to the VM Host Server by the VEPA capable bridge (today's bridges are typically not VEPA capable).

- `bridge`: packets whose destination is on the same VM Host Server as where they originate from are directly delivered to the target macvtap device. Both origin and destination devices need to be in `bridge` mode for direct delivery. If either of them is in `vepa` mode, a VEPA capable bridge is required.

- `private`: all packets are sent to the external bridge and delivered to a target VM Guest on the same VM Host Server if they are sent through an external router or gateway and that device sends them back to the VM Host Server. This procedure is followed if either the source or destination device is in private mode.

- `passthrough`: a special mode that gives more power to the network interface. All packets are forwarded to the interface, allowing virtio VM Guests to change the MAC address or set promiscuous mode to bridge the interface or create VLAN interfaces on top of it. Note that a network interface is not shareable in `passthrough` mode. Assigning an interface to a VM Guest disconnects it from the VM Host Server. For this reason SR-IOV virtual functions are often assigned to the VM Guest in `passthrough` mode.

14.16 Disabling a memory balloon device

Memory Balloon has become a default option for KVM. The device is added to the VM Guest explicitly, so you do not need to add this element in the VM Guest's XML configuration. If you want to disable Memory Balloon in the VM Guest for any reason, you need to set `model='none'` as shown below:

```
<devices>
   <memballoon model='none'/>
</device>
```

14.17 Configuring multiple monitors (dual head)

`libvirt` supports a dual head configuration to display the video output of the VM Guest on multiple monitors.

Important: No support for Xen

The Xen hypervisor does not support dual head configuration.

PROCEDURE 14.3: CONFIGURING DUAL HEAD

1. While the virtual machine is running, verify that the `xf86-video-qxl` package is installed in the VM Guest:

   ```
   > rpm -q xf86-video-qxl
   ```

2. Shut down the VM Guest and start editing its configuration XML as described in *Section 14.1, “Editing the VM configuration”*.

3. Verify that the model of the virtual graphics card is “qxl”:

   ```
   <video>
    <model type='qxl' ... />
   ```

4. Increase the `heads` parameter in the graphics card model specification from the default `1` to `2`, for example:

   ```
   <video>
    <model type='qxl' ram='65536' vram='65536' vgamem='16384' heads='2' primary='yes'/>
   ```

```
 <alias name='video0'/>
 <address type='pci' domain='0x0000' bus='0x00' slot='0x01' function='0x0'/>
</video>
```

5. Configure the virtual machine to use the Spice display instead of VNC:

   ```
   <graphics type='spice' port='5916' autoport='yes' listen='0.0.0.0'>
    <listen type='address' address='0.0.0.0'/>
   </graphics>
   ```

6. Start the virtual machine and connect to its display with **`virt-viewer`**, for example:

   ```
   > virt-viewer --connect qemu+ssh://USER@VM_HOST/system
   ```

7. From the list of VMs, select the one whose configuration you have modified and confirm with *Connect*.

8. After the graphical subsystem (Xorg) loads in the VM Guest, select *View* › *Displays* › *Display 2* to open a new window with the second monitor's output.

14.18 Crypto adapter pass-through to KVM guests on IBM Z

14.18.1 Introduction

IBM Z machines include cryptographic hardware with useful functions such as random number generation, digital signature generation, or encryption. KVM allows dedicating these crypto adapters to guests as pass-through devices. The means that the hypervisor cannot observe communications between the guest and the device.

14.18.2 What is covered

This section describes how to dedicate a crypto adapter and domains on an IBM Z host to a KVM guest. The procedure includes the following basic steps:

- Mask the crypto adapter and domains from the default driver on the host.

- Load the `vfio-ap` driver.

- Assign the crypto adapter and domains to the `vfio-ap` driver.
- Configure the guest to use the crypto adapter.

14.18.3 Requirements

- You need to have the QEMU / `libvirt` virtualization environment correctly installed and functional.
- The `vfio_ap` and `vfio_mdev` modules for the running kernel need to be available on the host operating system.

14.18.4 Dedicate a crypto adapter to a KVM host

1. Verify that the `vfio_ap` and `vfio_mdev` kernel modules are loaded on the host:

   ```
   > lsmod | grep vfio_
   ```

   If any of them is not listed, load it manually, for example:

   ```
   > sudo modprobe vfio_mdev
   ```

2. Create a new MDEV device on the host and verify that it was added:

   ```
   uuid=$(uuidgen)
   $ echo ${uuid} | sudo tee /sys/devices/vfio_ap/matrix/mdev_supported_types/vfio_ap-
   passthrough/create
   dmesg | tail
   [...]
   [272197.818811] iommu: Adding device 24f952b3-03d1-4df2-9967-0d5f7d63d5f2 to group 0
   [272197.818815] vfio_mdev 24f952b3-03d1-4df2-9967-0d5f7d63d5f2: MDEV: group_id = 0
   ```

3. Identify the device on the host's logical partition that you intend to dedicate to a KVM guest:

   ```
   > ls -l /sys/bus/ap/devices/
   [...]
   lrwxrwxrwx 1 root root 0 Nov 23 03:29 00.0016 -> ../../../devices/ap/card00/00.0016/
   lrwxrwxrwx 1 root root 0 Nov 23 03:29 card00 -> ../../../devices/ap/card00/
   ```

   In this example, it is card `0` queue `16`. To match the Hardware Management Console (HMC) configuration, you need to convert from `16` hexadecimal to `22` decimal.

4. Mask the adapter from the `zcrypt` use:

```
> lszcrypt
CARD.DOMAIN TYPE MODE STATUS REQUEST_CNT
-------------------------------------------------
00 CEX5C CCA-Coproc online 5
00.0016 CEX5C CCA-Coproc online 5
```

Mask the adapter:

```
> cat /sys/bus/ap/apmask
0xffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffff
echo -0x0 | sudo tee /sys/bus/ap/apmask
0x7fffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffff
```

Mask the domain:

```
> cat /sys/bus/ap/aqmask
0xffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffffff
echo -0x0 | sudo tee /sys/bus/ap/aqmask
0xfffffdffffffffffffffffffffffffffffffffffffffffffffffffffffffffff
```

5. Assign adapter 0 and domain 16 (22 decimal) to `vfio-ap`:

```
> sudo echo +0x0 > /sys/devices/vfio_ap/matrix/${uuid}/assign_adapter
> echo +0x16 | sudo tee /sys/devices/vfio_ap/matrix/${uuid}/assign_domain
> echo +0x16 | sudo tee /sys/devices/vfio_ap/matrix/${uuid}/assign_control_domain
```

6. Verify the matrix that you have configured:

```
> cat /sys/devices/vfio_ap/matrix/${uuid}/matrix
00.0016
```

7. Either create a new VM (refer to *Chapter 9, Guest installation*) and wait until it is initialized, or use an existing VM. In both cases, make sure the VM is shut down.

8. Change its configuration to use the MDEV device:

```
> sudo virsh edit VM_NAME
[...]
<hostdev mode='subsystem' type='mdev' model='vfio-ap'>
 <source>
  <address uuid='24f952b3-03d1-4df2-9967-0d5f7d63d5f2'/>
 </source>
</hostdev>
[...]
```

9. Restart the VM:

   ```
   > sudo virsh reboot VM_NAME
   ```

10. Log in to the guest and verify that the adapter is present:

    ```
    > lszcrypt
    CARD.DOMAIN TYPE MODE STATUS REQUEST_CNT
    -------------------------------------------------
    00 CEX5C CCA-Coproc online 1
    00.0016 CEX5C CCA-Coproc online 1
    ```

14.18.5 Further reading

- The installation of virtualization components is detailed in *Chapter 6, Installation of virtualization components*.
- The `vfio_ap` architecture is detailed in https://www.kernel.org/doc/Documentation/s390/vfio-ap.txt.
- A general outline together with a detailed procedure is described in https://bugs.launchpad.net/ubuntu/+source/linux/+bug/1787405.
- The architecture of VFIO Mediated devices (MDEVs) is detailed in https://www.kernel.org/doc/html/latest/driver-api/vfio-mediated-device.html.

15 Xen to KVM migration guide

As the KVM virtualization solution is becoming more and more popular among server administrators, many of them need a path to migrate their existing Xen based environments to KVM. As of now, there are no mature tools to automatically convert Xen VMs to KVM. There is, however, a technical solution that helps convert Xen virtual machines to KVM. The following information and procedures help you to perform such a migration.

Important: Migration procedure not supported

The migration procedure described in this document is not fully supported by SUSE. We provide it as a guidance only.

15.1 Migration to KVM using `virt-v2v`

This section contains information to help you import virtual machines from foreign hypervisors (such as Xen) to KVM managed by `libvirt`.

Tip: Microsoft Windows guests

This section is focused on converting Linux guests. Converting Microsoft Windows guests using **`virt-v2v`** is the same as converting Linux guests, except with regard to handling the Virtual Machine Driver Pack (VMDP). Additional details on converting Windows guests with the VMDP can be found separately at Virtual Machine Driver Pack documentation (https://documentation.suse.com/sle-vmdp/)↗.

15.1.1 Introduction to `virt-v2v`

`virt-v2v` is a command line tool to convert VM Guests from a foreign hypervisor to run on KVM managed by `libvirt`. It enables paravirtualized virtio drivers in the converted virtual machine if possible. A list of supported operating systems and hypervisors follows:

SUPPORTED GUEST OPERATING SYSTEMS

- SUSE Linux Enterprise Server

- openSUSE
- Red Hat Enterprise Linux
- Fedora
- Microsoft Windows Server 2003 and 2008

SUPPORTED SOURCE HYPERVISOR

- Xen

SUPPORTED TARGET HYPERVISOR

- KVM (managed by `libvirt`)

15.1.2 Installing **`virt-v2v`**

The installation of **`virt-v2v`** is simple:

```
> sudo zypper install virt-v2v
```

Remember that **`virt-v2v`** requires `root` privileges, so you need to run it either as `root`, or via **`sudo`**.

15.1.3 Converting virtual machines to run under KVM managed by `libvirt`

`virt-v2v` converts virtual machines from the Xen hypervisor to run under KVM managed by `libvirt`. To learn more about `libvirt` and **`virsh`**, see *Part II, “Managing virtual machines with `libvirt`”*. Additionally, all **`virt-v2v`** command line options are explained in the **`virt-v2v`** manual page (**`man 1 virt-v2v`**).

Before converting a virtual machine, make sure to complete the following steps:

PROCEDURE 15.1: PREPARING THE ENVIRONMENT FOR THE CONVERSION

1. Create a new local storage pool.

   `virt-v2v` copies the storage of the source virtual machine to a local storage pool managed by `libvirt` (the original disk image remains unchanged). You can create the pool either with Virtual Machine Manager or **`virsh`**. For more information, see *Section 8.2.2, “Managing storage with Virtual Machine Manager”* and *Section 8.2.1, “Managing storage with **`virsh`**”*.

2. Prepare the local network interface.

   Check that the converted virtual machine can use a local network interface on the VM Host Server. It is normally a network bridge and if it is not yet defined, create it with *YaST* › *System* › *Network Settings* › *Add* › *Bridge*.

Note: Mappings of network devices

Network devices on the source Xen host can be mapped during the conversion process to corresponding network devices on the KVM target host. For example, the Xen bridge `br0` can be mapped to the default KVM network device. Sample mappings can be found in `/etc/virt-v2v.conf`. To enable these mappings, modify the XML rule as necessary and ensure the section is not commented out with `<!--` and `-->` markers. For example:

```
<network type='bridge' name='br0'>
  <network type='network' name='default'/>
</network>
```

Tip: No network bridge

If there is no network bridge available, Virtual Machine Manager can optionally create it.

`virt-v2v` has the following basic command syntax:

```
virt-v2v -i INPUT_METHOD -os STORAGE_POOL SOURCE_VM
```

input_method

There are two input methods: `libvirt` or `libvirtxml`. See the *`SOURCE_VM`* parameter for more information.

storage_pool

The storage pool you already prepared for the target virtual machine.

source_vm

The source virtual machine to convert. It depends on the *`INPUT_METHOD`* parameter: for `libvirt`, specify the name of a libvirt domain. For `libvirtxml`, specify the path to an XML file containing a libvirt domain specification.

Note: Conversion time

Conversion of a virtual machine takes a lot of system resources, mainly for copying the whole disk image for a virtual machine. Converting a single virtual machine typically takes up to 10 minutes.Virtual machines using large disk images can take much longer.

15.1.3.1 Conversion based on the `libvirt` XML description file

This section describes how to convert a local Xen virtual machine using the `libvirt` XML configuration file. This method is suitable if the host is already running the KVM hypervisor. Make sure that the `libvirt` XML file of the source virtual machine, and the `libvirt` storage pool referenced from it are available on the local host.

1. Obtain the `libvirt` XML description of the source virtual machine.

   #### Tip: Obtaining the XML files

   To obtain the `libvirt` XML files of the source virtual machine, you must run the host OS under the Xen kernel. If you already rebooted the host to the KVM-enabled environment, reboot back to the Xen kernel, dump the `libvirt` XML file, and then reboot back to the KVM environment.

   First identify the source virtual machine under virsh:

   ```
   # virsh list
    Id    Name                           State
   ----------------------------------------------------
   [...]
     2     sles12_xen                     running
   [...]
   ```

   `sles12_xen` is the source virtual machine to convert. Now export its XML and save it to `sles12_xen.xml`:

   ```
   # virsh dumpxml sles12_xen > sles12_xen.xml
   ```

2. Verify that all disk image paths are correct from the KVM host's perspective. This is not a problem when converting on one machine, but may require manual changes when converting using an XML dump from another host.

```
<source file='/var/lib/libvirt/images/XenPool/SLES.qcow2'/>
```

Tip: Copying images

To avoid copying an image twice, manually copy the disk image or images directly to the `libvirt` storage pool. Update the source file entries in the XML description file. The **`virt-v2v`** process detects the existing disks and converts them in place.

3. Run **`virt-v2v`** to convert to KVM virtual machine:

```
# virt-v2v sles12_xen.xml❶ \
-i LIBVIRTXML❷ \
-os remote_host.example.com:/exported_dir❸ \
--bridge br0❹ \
-on sles12_kvm❺
```

❶ The XML description of the source Xen-based virtual machine.

❷ **`virt-v2v`** reads the information about the source virtual machine from a `libvirt` XML file.

❸ Storage pool where the target virtual machine disk image is placed. In this example, the image is placed on an NFS share `/exported_dir` on the `remote_host.example.com` server.

❹ The target KVM-based virtual machine uses the network bridge `br0` on the host.

❺ The target virtual machine is renamed to `sles12_kvm` to prevent name collision with the existing virtual machine of the same name.

15.1.3.2 Conversion based on the `libvirt` domain name

This method is useful if you are still running `libvirt` under Xen, and plan to reboot to the KVM hypervisor later.

1. Find the `libvirt` domain name of the virtual machine you want to convert.

```
# virsh list
 Id    Name                           State
-----------------------------------------------------
[...]
  2     sles12_xen                     running
```

```
[...]
```

`sles12_xen` is the source virtual machine to convert.

2. Run **`virt-v2v`** to convert to KVM virtual machine:

```
# virt-v2v sles12_xen❶ \
-i libvirt❷ \
-os storage_pool❸ \
--network eth0❹ \
-of qcow2❺ \
-oa sparse❻ \
-on sles12_kvm
```

❶ The domain name of the Xen-based virtual machine.

❷ **`virt-v2v`** reads the information about the source virtual machine directly from the active `libvirt` connection.

❸ The target disk image is placed in a local `libvirt` storage pool.

❹ All guest bridges (or networks) are connected to a locally managed network.

❺ Format for the disk image of the target virtual machine. Supported options are `raw` or `qcow2`.

❻ Whether the converted guest disk space is `sparse` or `preallocated`.

15.1.3.3 Converting a remote Xen virtual machine

This method is useful if you need to convert a Xen virtual machine running on a remote host. As **`virt-v2v`** connects to the remote host via **`ssh`**, ensure the SSH service is running on the host.

Note: Passwordless SSH access

`virt-v2v` requires a passwordless SSH connection to the remote host. This means a connection using an SSH key added to the ssh-agent. See **`man ssh-keygen`** and **`man ssh-add`** for more details on this. More information is also available at *Book* “Security and Hardening Guide”, *Chapter 22 “Securing network operations with OpenSSH”*.

To connect to a remote `libvirt` connection, construct a valid connection URI relevant for your remote host. In the following example, the remote host name is `remote_host.example.com`, and the user name for the connection is `root`. The connection URI then looks as follows:

```
xen+ssh://root@remote_host.example.com/
```

For more information on `libvirt` connection URIs, see https://libvirt.org/uri.html ↗.

1. Find the `libvirt` domain name of the remote virtual machine you want to convert.

   ```
   # virsh -c xen+ssh://root@remote_host.example.com/ list
    Id    Name                           State
   ----------------------------------------------------
     1     sles12_xen                     running
   [...]
   ```

   `sles12_xen` is the source virtual machine to convert.

2. The **`virt-v2v`** command for the remote connection looks like this:

   ```
   # virt-v2v sles12_xen \
   -i libvirt \
   -ic xen+ssh://root@remote_host.example.com/ \
   -os local_storage_pool \
   --bridge br0
   ```

15.1.4 Running converted virtual machines

After **`virt-v2v`** completes successfully, a new `libvirt` domain is created with the name specified with the `-on` option. If you did not specify `-on`, the same name as the source virtual machine is used. The new guest can be managed with standard `libvirt` tools, such as **`virsh`** or Virtual Machine Manager.

Tip: Rebooting the machine

If you completed the conversion under Xen as described in *Section 15.1.3.2, “Conversion based on the `libvirt` domain name”*, you may need to reboot the host machine and boot with the non-Xen kernel.

15.2 Xen to KVM manual migration

15.2.1 General outline

The preferred solution to manage virtual machines is based on `libvirt`; for more information, see https://libvirt.org/ ↗. It has several advantages over the manual way of defining and running virtual machines— `libvirt` is cross-platform, supports many hypervisors, has secure remote management, has virtual networking, and, most of all, provides a unified abstract layer to manage virtual machines. Therefore the main focus of this article is on the `libvirt` solution.

Generally, the Xen to KVM migration consists of the following basic steps:

1. Make a backup copy of the original Xen VM Guest.

2. Optionally, apply changes specific to paravirtualized guests.

3. Obtain information about the original Xen VM Guest and update it to KVM equivalents.

4. Shut down the guest on the Xen host, and run the new one under the KVM hypervisor.

Warning: No live migration

The Xen to KVM migration cannot be done live while the source VM Guest is running. Before running the new KVM-ready VM Guest, you are advised to shut down the original Xen VM Guest.

15.2.2 Back up the Xen VM Guest

To back up your Xen VM Guest, follow these steps:

1. Identify the relevant Xen guest you want to migrate, and remember its ID/name.

```
> sudo virsh list --all
Id Name                    State
----------------------------------
 0 Domain-0                running
 1 SLES15SP3               running
[...]
```

2. Shut down the guest. You can do this either by shutting down the guest OS, or with **virsh**:

   ```
   > sudo virsh shutdown SLES11SP3
   ```

3. Back up its configuration to an XML file.

   ```
   > sudo virsh dumpxml SLES11SP3 > sles11sp3.xml
   ```

4. Back up its disk image file. Use the **cp** or **rsync** commands to create the backup copy. Remember that it is always a good idea to check the copy with the **md5sum** command.

5. After the image file is backed up, you can start the guest again with

   ```
   > sudo virsh start SLES11SP3
   ```

15.2.3 Changes specific to paravirtualized guests

Apply the following changes if you are migrating a paravirtualized Xen guest. You can do it either on the running guest, or on the stopped guest using `guestfs-tools`.

Important

After applying the changes described in this section, the image file related to the migrated VM Guest is not usable under Xen anymore.

15.2.3.1 Install the default kernel

Warning: No booting

After installing the default kernel, the system fails to boot the Xen guest.

Before cloning the Xen guest disk image for use under the KVM hypervisor, make sure it is bootable *without* the Xen hypervisor. This is crucial for paravirtualized Xen guests as they normally contain a special Xen kernel, and often do not have a complete GRUB 2 boot loader installed.

1. For SLES 11, update the `/etc/sysconfig/kernel` file. Change the `INITRD_MODULES` parameter by removing all Xen drivers and replacing them with virtio drivers. Replace

```
INITRD_MODULES="xenblk xennet"
```

with

```
INITRD_MODULES="virtio_blk virtio_pci virtio_net virtio_balloon"
```

For SLES 12, 15, and openSUSE search for `xenblk xennet` in `/etc/dracut.conf.d/*.conf` and replace them with `virtio_blk virtio_pci virtio_net virtio_balloon`

2. Paravirtualized Xen guests run a specific Xen kernel. To run the guest under KVM, you need to install the default kernel.

Note: Default kernel is already installed

You do not need to install the default kernel for a fully virtualized guest, as it is already installed.

Enter **`rpm -q kernel-default`** on the Xen guest to find out whether the default kernel is installed. If not, install it with **`zypper in kernel-default`**.
The kernel we are going to use to boot the guest under KVM must have *virtio* (paravirtualized) drivers available. Run the following command to find out. Do not forget to replace `5.3.18-8` with your kernel version:

```
> sudo sudo find /lib/modules/5.3.18-8-default/kernel/drivers/ -name virtio*
/lib/modules/5.3.18-8-default/kernel/drivers/block/virtio_blk.ko
/lib/modules/5.3.18-8-default/kernel/drivers/char/hw_random/virtio-rng.ko
/lib/modules/5.3.18-8-default/kernel/drivers/char/virtio_console.ko
/lib/modules/5.3.18-8-default/kernel/drivers/crypto/virtio
...
```

3. Update `/etc/fstab`. Change any storage devices from `xvda` to `vda`.

4. Update the boot loader configuration. Enter **`rpm -q grub2`** on the Xen guest to find out whether GRUB 2 is already installed. If not, install it with **`zypper in grub2`**.

Now make the newly installed default kernel the default for booting the OS. Also remove/update the kernel command line options that may refer to Xen-specific devices. You can do it either with YaST (*System* › *Boot Loader*), or manually:

- Find the preferred Linux boot menu entry by listing them all:

  ```
  > cat /boot/grub2/grub.cfg | grep 'menuentry '
  ```

  Remember the order number (counted from zero) of the one you newly installed.

- Set it as the default boot menu entry:

  ```
  > sudo grub2-set-default N
  ```

  Replace `N` with the number of the boot menu entry you previously discovered.

- Open `/etc/default/grub` for editing, and look for the `GRUB_CMDLINE_LINUX_DEFAULT` and `GRUB_CMDLINE_LINUX_RECOVERY` options. Remove or update any reference to Xen-specific devices. In the following example, you can replace

  ```
  root=/dev/xvda1 disk=/dev/xvda console=xvc
  ```

  with

  ```
  root=/dev/vda1 disk=/dev/vda
  ```

  Do not forget to remove all references to `xvc`-type consoles (such as `xvc0`).

5. Update `device.map` in either the `/boot/grub2` or `/boot/grub2-efi` directory, whichever that VM uses. Change any storage devices from `xvda` to `vda`.

6. To import new default settings, run

   ```
   grub2-mkconfig -o /boot/grub2/grub.cfg
   ```

15.2.3.2 Update the guest for boot under KVM

1. Update the system to use the default serial console. List the configured consoles, and remove symbolic links to `xvc?` ones.

   ```
   > sudo ls -l /etc/systemd/system/getty.target.wants/
   getty@tty1.service -> /usr/lib/systemd/system/getty@.service
   getty@xvc0.service -> /usr/lib/systemd/system/getty@xvc0.service
   ```

```
getty@xvc1.service -> /usr/lib/systemd/system/getty@xvc1.service

# rm /etc/systemd/system/getty.target.wants/getty@xvc?.service
```

2. Update the `/etc/securetty` file. Replace `xvc0` with `ttyS0`.

15.2.4 Update the Xen VM Guest configuration

This section describes how to export the configuration of the original Xen VM Guest, and what particular changes to apply to it so it can be imported as a KVM guest into `libvirt`.

15.2.4.1 Export the Xen VM Guest configuration

First export the configuration of the guest and save it to a file. For example:

```
> sudo virsh dumpxml SLES11SP3
<domain type='xen'>
  <name>SLES11SP3</name>
  <uuid>fa9ea4d7-8f95-30c0-bce9-9e58ffcabeb2</uuid>
  <memory>524288</memory>
  <currentMemory>524288</currentMemory>
  <vcpu>1</vcpu>
  <bootloader>/usr/bin/pygrub</bootloader>
  <os>
    <type>linux</type>
  </os>
  <clock offset='utc'/>
  <on_poweroff>destroy</on_poweroff>
  <on_reboot>restart</on_reboot>
  <on_crash>restart</on_crash>
  <devices>
    <emulator>/usr/lib/xen/bin/qemu-dm</emulator>
    <disk type='file' device='disk'>
      <driver name='file'/>
      <source file='/var/lib/libvirt/images/SLES_11_SP2_JeOS.x86_64-0.0.2_para.raw'/>
      <target dev='xvda' bus='xen'/>
    </disk>
    <interface type='bridge'>
      <mac address='00:16:3e:2d:91:c3'/>
      <source bridge='br0'/>
      <script path='vif-bridge'/>
    </interface>
    <console type='pty'>
      <target type='xen' port='0'/>
    </console>
    <input type='mouse' bus='xen'/>
    <graphics type='vnc' port='-1' autoport='yes' keymap='en-us'/>
  </devices>
</domain>
```

You can find detailed information on the libvirt XML format for VM Guest description at https://libvirt.org/formatdomain.html.

15.2.4.2 General changes to the guest configuration

You need to make a few general changes to the exported Xen guest XML configuration to run it under the KVM hypervisor. The following applies to both fully virtualized and paravirtualized guests. The following XML elements are just an example and do not need to be in your specific configuration.

Tip: Conventions used

To refer to a node in the XML configuration file, an XPath syntax is used throughout this document. For example, to refer to a `<name>` inside the `<domain>` tag

```
<domain>
  <name>sles11sp3</name>
</domain>
```

an XPath equivalent `/domain/name` is used.

1. Change the `type` attribute of the `/domain` element from `xen` to `kvm`.
2. Remove the `/domain/bootloader` element section.
3. Remove the `/domain/bootloader_args` element section.
4. Change the `/domain/os/type` element value from `linux` to `hvm`.
5. Add `<boot dev="hd"/>` under the `/domain/os` element.
6. Add the `arch` attribute to the `/domain/os/type` element. Acceptable values are `arch=”x86_64”` or `arch=”i686”`
7. Change the `/domain/devices/emulator` element from `/usr/lib/xen/bin/qemu-dm'` to `/usr/bin/qemu-kvm`.

8. For each disk associated with the paravirtualized (PV) guest, change the following:

   - Change the `name` attribute of the `/domain/devices/disk/driver` element from `file` to `qemu`, and add a `type` attribute for the disk type. For example, valid options include `raw` and `qcow2`.

   - Change the `dev` attribute of the `/domain/devices/disk/target` element from `xvda` to `vda`.

   - Change the `bus` attribute of the `/domain/devices/disk/target` element from `xen` to `virtio`.

9. For each network interface card, make the following changes:

   - If there is a `model` defined in `/domain/devices/interface`, change its `type` attribute value to `virtio`

     ```
     <model type=”virtio”>
     ```

   - Delete all `/domain/devices/interface/script` sections.

   - Delete all `/domain/devices/interface/target` elements if the `dev` attribute starts with `vif` or `vnet` or `veth`. If using a custom network then change the `dev` value to that target.

10. Remove the `/domain/devices/console` element section if it exists.

11. Remove the `/domain/devices/serial` element section if it exists.

12. Change the `bus` attribute on the `/domain/devices/input` element from `xen` to `ps2`.

13. Add the following element for memory ballooning features under the `/domain/devices` element.

    ```
    <memballoon model="virtio"/>
    ```

Tip: Device name

`<target dev='hda' bus='ide'/>` controls the device under which the disk is exposed to the guest OS. The `dev` attribute indicates the “logical” device name. The actual device name specified is not guaranteed to map to the device name in the guest OS. Therefore you may need to change the disk mapping on the boot loader command line. For example, if the boot loader expects a root disk to be `hda2` but KVM still sees it as `sda2`, change the boot loader command line from

```
[...] root=/dev/hda2 resume=/dev/hda1 [...]
```

to

```
[...] root=/dev/sda2 resume=/dev/sda1 [...]
```

For paravirtualized `xvda` devices, change it to:

```
[...] root=/dev/vda2 resume=/dev/vda1 [...]
```

Otherwise the VM Guest refuses to boot in the KVM environment.

15.2.4.3 The target KVM guest configuration

After having applied all the modifications mentioned above, you end up with the following configuration for your KVM guest:

```
<domain type='kvm'>
  <name>SLES11SP3</name>
  <uuid>fa9ea4d7-8f95-30c0-bce9-9e58ffcabeb2</uuid>
  <memory>524288</memory>
  <currentMemory>524288</currentMemory>
  <vcpu cpuset='0-3'>1</vcpu>
  <os>
    <type arch=”x86_64”>hvm</type>
    <boot dev="hd"/>
  </os>
  <clock offset='utc'/>
  <on_poweroff>destroy</on_poweroff>
  <on_reboot>restart</on_reboot>
  <on_crash>restart</on_crash>
  <devices>
    <emulator>/usr/bin/qemu-kvm</emulator>
    <disk type='file' device='disk'>
      <driver name='qemu' type="raw"/>
      <source file='/var/lib/libvirt/images/SLES_11_SP2_JeOS.x86_64-0.0.2_para.raw'/>
      <target dev='vda' bus='virtio'/>
    </disk>
    <interface type='bridge'>
      <mac address='00:16:3e:2d:91:c3'/>
      <source bridge='br0'/>
    </interface>
    <input type='mouse' bus='usb'/>
    <graphics type='vnc' port='5900' autoport='yes' keymap='en-us'/>
    <memballoon model="virtio"/>
  </devices>
</domain>
```

Save the configuration to a file in your home directory, as `SLES11SP3.xml`, for example. It gets copied to the default `/etc/libvirt/qemu` directory after the import.

15.2.5 Migrate the VM Guest

After you updated the VM Guest configuration, and applied necessary changes to the guest OS, shut down the original Xen guest, and run its clone under the KVM hypervisor.

1. Shut down the guest on the Xen host by running **`shutdown -h now`** as `root` from the console.

2. Copy the disk images associated with the VM Guest if needed. A default configuration requires the Xen disk files to be copied from `/var/lib/xen/images` to `/var/lib/kvm/images`. The `/var/lib/kvm/images` directory may need to be created (as `root`) if you have not previously created a VM Guest.

3. Create the new domain, and register it with `libvirt`:

   ```
   > sudo virsh define SLES11SP3.xml
    Domain SLES11SP3 defined from SLES11SP3.xml
   ```

4. Verify that the new guest is seen in the KVM configuration:

   ```
   > virsh list –all
   ```

5. After the domain is created, you can start it:

   ```
   > sudo virsh start SLES11SP3
    Domain SLES11SP3 started
   ```

15.3 More information

For more information on libvirt, see https://libvirt.org.

You can find more details on the `libvirt` XML format at https://libvirt.org/formatdomain.html ↗.

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16 Disk cache modes

16.1 What is a disk cache?

A disk cache is a memory used to speed up the process of storing and accessing data from the hard disk. Physical hard disks have their cache integrated as a standard feature. For virtual disks, the cache uses VM Host Server's memory and you can fine-tune its behavior, for example, by setting its type.

16.2 How does a disk cache work?

Normally, a disk cache stores the most recent and frequently used programs and data. When a user or program requests data, the operating system first checks the disk cache. If the data is there, the operating system quickly delivers the data to the program instead of re-reading the data from the disk.

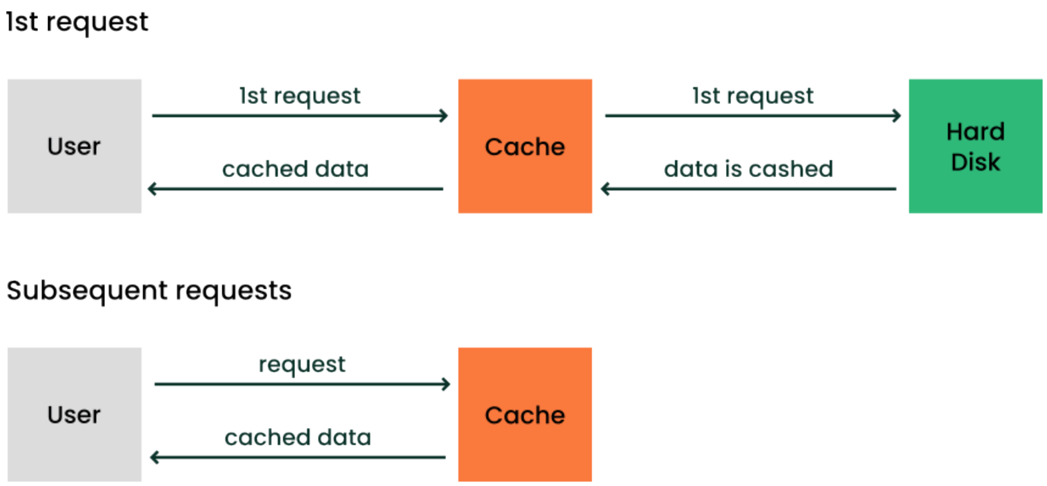

FIGURE 16.1: CACHING MECHANISM

16.3 Benefits of disk caching

Caching of virtual disk devices affects the overall performance of guest machines. You can improve the performance by optimizing the combination of cache mode, disk image format, and storage subsystem.

16.4 Virtual disk cache modes

If you do not specify a cache mode, `writeback` is used by default. Each guest disk can use one of the following cache modes:

writeback

`writeback` uses the host page cache. Writes are reported to the guest as completed when they are placed in the host cache. Cache management handles commitment to the storage device. The guest's virtual storage adapter is informed of the *writeback* cache and therefore expected to send flush commands as needed to manage data integrity.

writethrough

Writes are reported as completed only when the data has been committed to the storage device. The guest's virtual storage adapter is informed that there is no *writeback* cache, so the guest does not need to send flush commands to manage data integrity.

none

The host cache is bypassed, and reads and writes happen directly between the hypervisor and the storage device. Because the actual storage device may report a write as completed when the data is still placed in its write queue only, the guest's virtual storage adapter is informed that there is a *writeback* cache. This mode is equivalent to direct access to the host's disk.

unsafe

Similar to the *writeback* mode, except all flush commands from the guests are ignored. Using this mode implies that the user prioritizes performance gain over the risk of data loss in case of a host failure. This mode can be useful during guest installation, but not for production workloads.

directsync

Writes are reported as completed only when the data has been committed to the storage device and the host cache is bypassed. Similar to *writethrough*, this mode can be useful for guests that do not send flushes when needed.

16.5 Cache modes and data integrity

writethrough, none, directsync

These modes are considered to be safest when the guest operating system uses flushes as needed. For unsafe or unstable guests, use *writethough* or *directsync*.

writeback

This mode informs the guest of the presence of a write cache, and it relies on the guest to send flush commands as needed to maintain data integrity within its disk image. This mode exposes the guest to data loss if the host fails. The reason is the gap between the moment a write is reported as completed and the time the write being committed to the storage device.

unsafe

This mode is similar to *writeback* caching, except the guest flush commands are ignored. This means a higher risk of data loss caused by host failure.

16.6 Cache modes and live migration

The caching of storage data restricts the configurations that support live migration. Currently, only `raw` and `qcow2` image formats can be used for live migration. If a clustered file system is used, all cache modes support live migration. Otherwise the only cache mode that supports live migration on read/write shared storage is `none`.

The `libvirt` management layer includes checks for migration compatibility based on several factors. If the guest storage is hosted on a clustered file system, is read-only, or is marked shareable, then the cache mode is ignored when determining if migration can be allowed. Otherwise `libvirt` does not allow migration unless the cache mode is set to `none`. However, this restriction can be overridden with the “--unsafe” option to the migration APIs, which is also supported by **`virsh`**. For example

```
> virsh migrate --live --unsafe
```

Tip

The cache mode `none` is required for the AIO mode setting `native`. If another cache mode is used, the AIO mode is silently switched back to the default `threads`.

17 VM Guest clock settings

Keeping the correct time in a VM Guest is one of the more difficult aspects of virtualization. Keeping the correct time is especially important for network applications and is also a prerequisite to do a live migration of a VM Guest.

Tip: Timekeeping on the VM Host Server

It is strongly recommended to ensure the VM Host Server keeps the correct time as well, for example, by using NTP (see *Book "Reference", Chapter 18 "Time synchronization with NTP"* for more information).

17.1 KVM: using `kvm_clock`

KVM provides a paravirtualized clock which is supported via the `kvm_clock` driver. It is strongly recommended to use `kvm_clock`.

Use the following command inside a VM Guest running Linux to check whether the driver `kvm_clock` has been loaded:

```
> sudo dmesg | grep kvm-clock
[    0.000000] kvm-clock: cpu 0, msr 0:7d3a81, boot clock
[    0.000000] kvm-clock: cpu 0, msr 0:1206a81, primary cpu clock
[    0.012000] kvm-clock: cpu 1, msr 0:1306a81, secondary cpu clock
[    0.160082] Switching to clocksource kvm-clock
```

To check which clock source is currently used, run the following command in the VM Guest. It should output `kvm-clock`:

```
> cat /sys/devices/system/clocksource/clocksource0/current_clocksource
```

Important: `kvm-clock` and NTP

When using `kvm-clock`, it is recommended to use NTP in the VM Guest, as well. Using NTP on the VM Host Server is also recommended.

17.1.1 Other timekeeping methods

The paravirtualized `kvm-clock` is currently not for Windows* operating systems. For Windows*, use the `Windows Time Service Tools` for time synchronization.

17.2 Xen virtual machine clock settings

With Xen 4, the independent wallclock setting `/proc/sys/xen/independent_wallclock` used for time synchronization between Xen host and guest was removed. A new configuration option `tsc_mode` was introduced. It specifies a method of using the *time stamp counter* to synchronize the guest time with the Xen server. Its default value 0 handles the most hardware and software environments.

For more details on `tsc_mode`, see the `xen-tscmode` manual page (**`man 7 xen-tscmode`**).

18 libguestfs

*Virtual Machine*s consist of disk images and definition files. Manually accessing and manipulating these guest components (outside of normal hypervisor processes) is possible, but inherently dangerous and risks compromising data integrity. libguestfs is a C library and a corresponding set of tools designed for safely accessing and modifying *Virtual Machine* disk images—outside of normal hypervisor processes, but without the risk normally associated with manual editing.

> **Important**
>
> Using libguestfs tools is fully supported on the AMD64/Intel 64 architecture only.

18.1 VM Guest manipulation overview

18.1.1 VM Guest manipulation risk

As disk images and definition files are simply another type of file in a Linux environment, it is possible to use many tools to access, edit and write to these files. When used correctly, such tools can be an important part of guest administration. However, even correct usage of these tools is not without risk. Risks that should be considered when manually manipulating guest disk images include:

- *Data Corruption*: concurrently accessing images, by the host machine or another node in a cluster, can cause changes to be lost or data corruption to occur if virtualization protection layers are bypassed.
- *Security*: mounting disk images as loop devices requires root access. While an image is loop mounted, other users and processes can potentially access the disk contents.
- *Administrator Error*: bypassing virtualization layers correctly requires advanced understanding of virtual components and tools. Failing to isolate the images or failing to clean up properly after changes have been made can lead to further problems once back in virtualization control.

18.1.2 libguestfs design

libguestfs C library has been designed to safely and securely create, access and modify virtual machine (VM Guest) disk images. It also provides additional language bindings: for Perl (https://libguestfs.org/guestfs-perl.3.html) ↗, Python (https://libguestfs.org/guestfs-python.3.html) ↗, PHP (only for 64-bit machines), and Ruby (https://libguestfs.org/guestfs-ruby.3.html) ↗. libguestfs can access VM Guest disk images without needing root and with multiple layers of defense against rogue disk images.

libguestfs provides many tools designed for accessing and modifying VM Guest disk images and contents. These tools provide such capabilities as: viewing and editing files inside guests, scripting changes to VM Guests, monitoring disk used/free statistics, creating guests, doing V2V or P2V migrations, performing backups, cloning VM Guests, formatting disks, and resizing disks.

Warning: Best practices

You must not use libguestfs tools on live virtual machines. Doing so may result in disk corruption in the VM Guest. libguestfs tools try to stop you from doing this, but cannot catch all cases.

However, most commands have the `--ro` (read-only) option. With this option, you can run a command on a live virtual machine. The results may be strange or inconsistent but you do not risk disk corruption.

18.2 Package installation

libguestfs is shipped through 4 packages:

- `libguestfs0`: which provides the main C library
- `guestfs-data`: which contains the appliance files used when launching images (stored in `/usr/lib64/guestfs`)
- `guestfs-tools`: the core guestfs tools, man pages, and the `/etc/libguestfs-tools.conf` configuration file.
- `guestfs-winsupport`: provides support for Windows file guests in the guestfs tools. This package only needs to be installed to handle Windows guests, for example when converting a Windows guest to KVM.

To install guestfs tools on your system run:

```
> sudo zypper in guestfs-tools
```

18.3 Guestfs tools

18.3.1 Modifying virtual machines

The set of tools found within the guestfs-tools package is used for accessing and modifying virtual machine disk images. This functionality is provided through a familiar shell interface with built-in safeguards which ensure image integrity. Guestfs tools shells expose all capabilities of the guestfs API, and create an appliance on the fly using the packages installed on the machine and the files found in `/usr/lib64/guestfs`.

18.3.2 Supported file systems and disk images

Guestfs tools support multiple file systems including:

- Ext2, Ext3, Ext4
- Xfs
- Btrfs

Multiple disk image formats are also supported:

- raw
- qcow2

Warning: Unsupported file systems

Guestfs may also support Windows* file systems (VFAT, NTFS), BSD* and Apple* file systems, and other disk image formats (VMDK, VHDX...). However, these file systems and disk image formats are unsupported on openSUSE Leap.

18.3.3 virt-rescue

virt-rescue is similar to a rescue CD, but for virtual machines, and without the need for a CD. virt-rescue presents users with a rescue shell and several simple recovery tools which can be used to examine and correct problems within a virtual machine or disk image.

```
> virt-rescue -a sles.qcow2
Welcome to virt-rescue, the libguestfs rescue shell.

Note: The contents of / are the rescue appliance.
You need to mount the guest's partitions under /sysroot
before you can examine them. A helper script for that exists:
mount-rootfs-and-do-chroot.sh /dev/sda2

><rescue>
[   67.194384] EXT4-fs (sda1): mounting ext3 file system
using the ext4 subsystem
[   67.199292] EXT4-fs (sda1): mounted filesystem with ordered data
mode. Opts: (null)
mount: /dev/sda1 mounted on /sysroot.
mount: /dev bound on /sysroot/dev.
mount: /dev/pts bound on /sysroot/dev/pts.
mount: /proc bound on /sysroot/proc.
mount: /sys bound on /sysroot/sys.
Directory: /root
Thu Jun  5 13:20:51 UTC 2014
(none):~ #
```

You are now running the VM Guest in rescue mode:

```
(none):~ # cat /etc/fstab
devpts  /dev/pts          devpts  mode=0620,gid=5 0 0
proc    /proc             proc    defaults        0 0
sysfs   /sys              sysfs   noauto          0 0
debugfs /sys/kernel/debug debugfs noauto          0 0
usbfs   /proc/bus/usb     usbfs   noauto          0 0
tmpfs   /run              tmpfs   noauto          0 0
/dev/disk/by-id/ata-QEMU_HARDDISK_QM00001-part1 / ext3 defaults 1 1
```

18.3.4 virt-resize

virt-resize is used to resize a virtual machine disk, making it larger or smaller overall, and resizing or deleting any partitions contained within.

PROCEDURE 18.1: EXPANDING A DISK

Full step-by-step example: how to expand a virtual machine disk

1. First, with virtual machine powered off, determine the size of the partitions available on this virtual machine:

```
> virt-filesystems --long --parts --blkdevs -h -a sles.qcow2
Name       Type       MBR  Size  Parent
/dev/sda1  partition  83   16G   /dev/sda
/dev/sda   device     -    16G   -
```

2. **`virt-resize`** cannot do in-place disk modifications—there must be sufficient space to store the resized output disk. Use the **`truncate`** command to create a file of suitable size:

```
> truncate -s 32G outdisk.img
```

3. Use **`virt-resize`** to resize the disk image. **`virt-resize`** requires two mandatory parameters for the input and output images:

```
> virt-resize --expand /dev/sda1 sles.qcow2 outdisk.img
Examining sles.qcow2 ...
**********
Summary of changes:

/dev/sda1: This partition will be resized from 16,0G to 32,0G.  The
    filesystem ext3 on /dev/sda1 will be expanded using the 'resize2fs'
    method.

**********
Setting up initial partition table on outdisk.img ...
Copying /dev/sda1 ...
◐ 84%
⟦▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒════════⟧ 00:03
Expanding /dev/sda1 using the 'resize2fs' method ...

Resize operation completed with no errors.  Before deleting the old
disk, carefully check that the resized disk boots and works correctly.
```

4. Confirm the image was resized properly:

```
> virt-filesystems --long --parts --blkdevs -h -a outdisk.img
Name       Type       MBR  Size  Parent
/dev/sda1  partition  83   32G   /dev/sda
/dev/sda   device     -    32G   -
```

5. Bring up the VM Guest using the new disk image and confirm correct operation before deleting the old image.

18.3.5 Other virt-* tools

There are guestfs tools to simplify administrative tasks—such as viewing and editing files, or obtaining information on the virtual machine.

18.3.5.1 `virt-filesystems`

This tool is used to report information regarding file systems, partitions and logical volumes in a disk image or virtual machine.

```
> virt-filesystems -l -a sles.qcow2
Name       Type        VFS   Label  Size         Parent
/dev/sda1  filesystem  ext3  -      17178820608  -
```

18.3.5.2 `virt-ls`

`virt-ls` lists file names, file sizes, checksums, extended attributes and more from a virtual machine or disk image. Multiple directory names can be given, in which case the output from each is concatenated. To list directories from a libvirt guest, use the `-d` option to specify the name of the guest. For a disk image, use the `-a` option.

```
> virt-ls -h -lR -a sles.qcow2 /var/log/
d 0755        776 /var/log
- 0640          0 /var/log/NetworkManager
- 0644        23K /var/log/Xorg.0.log
- 0644        23K /var/log/Xorg.0.log.old
d 0700        482 /var/log/YaST2
- 0644        512 /var/log/YaST2/_dev_vda
- 0644         59 /var/log/YaST2/arch.info
- 0644        473 /var/log/YaST2/config_diff_2017_05_03.log
- 0644       5.1K /var/log/YaST2/curl_log
- 0644       1.5K /var/log/YaST2/disk_vda.info
- 0644       1.4K /var/log/YaST2/disk_vda.info-1
[...]
```

18.3.5.3 virt-cat

virt-cat is a command line tool to display the contents of a file that exists in the named virtual machine (or disk image). Multiple file names can be given, in which case they are concatenated together. Each file name must be specified by its absolute path, starting at the root directory with `/`.

```
> virt-cat -a sles.qcow2 /etc/fstab
devpts /dev/pts devpts mode=0620,gid=5 0 0
proc   /proc    proc   defaults       0 0
```

18.3.5.4 virt-df

virt-df is a command line tool to display free space on virtual machine file systems. Unlike other tools, it not only displays the size of disk allocated to a virtual machine, but can look inside disk images to show how much space is being used.

```
> virt-df -a sles.qcow2
Filesystem                           1K-blocks       Used  Available  Use%
sles.qcow2:/dev/sda1                  16381864     520564   15022492   4%
```

18.3.5.5 virt-edit

virt-edit is a command line tool capable of editing files that reside in the named virtual machine (or disk image).

18.3.5.6 virt-tar-in/out

virt-tar-in unpacks an uncompressed TAR archive into a virtual machine disk image or named libvirt domain. **virt-tar-out** packs a virtual machine disk image directory into a TAR archive.

```
> virt-tar-out -a sles.qcow2 /home homes.tar
```

18.3.5.7 virt-copy-in/out

virt-copy-in copies files and directories from the local disk into a virtual machine disk image or named libvirt domain. **virt-copy-out** copies files and directories out of a virtual machine disk image or named libvirt domain.

```
> virt-copy-in -a sles.qcow2 data.tar /tmp/
> virt-ls -a sles.qcow2 /tmp/
.ICE-unix
.X11-unix
data.tar
```

18.3.5.8 virt-log

virt-log shows the log files of the named libvirt domain, virtual machine or disk image. If the package `guestfs-winsupport` is installed it can also show the event log of a Windows virtual machine disk image.

```
> virt-log -a windows8.qcow2
<?xml version="1.0" encoding="utf-8" standalone="yes" ?>
<Events>
<Event xmlns="http://schemas.microsoft.com/win/2004/08/events/event"><System><Provider
 Name="EventLog"></Provider>
<EventID Qualifiers="32768">6011</EventID>
<Level>4</Level>
<Task>0</Task>
<Keywords>0x0080000000000000</Keywords>
<TimeCreated SystemTime="2014-09-12 05:47:21"></TimeCreated>
<EventRecordID>1</EventRecordID>
<Channel>System</Channel>
<Computer>windows-uj49s6b</Computer>
<Security UserID=""></Security>
</System>
<EventData><Data><string>WINDOWS-UJ49S6B</string>
<string>WIN-KG190623QG4</string>
</Data>
<Binary></Binary>
</EventData>
</Event>

...
```

18.3.6 `guestfish`

`guestfish` is a shell and command line tool for examining and modifying virtual machine file systems. It uses libguestfs and exposes all the functionality of the guestfs API.

Examples of usage:

```
> guestfish -a disk.img <<EOF
run
list-filesystems
EOF
```

```
guestfish

Welcome to guestfish, the guest filesystem shell for
editing virtual machine filesystems and disk images.

Type: 'help' for help on commands
      'man' to read the manual
      'quit' to quit the shell

><fs> add sles.qcow2
><fs> run
><fs> list-filesystems
/dev/sda1: ext3
><fs> mount /dev/sda1 /
 cat /etc/fstab
devpts  /dev/pts          devpts  mode=0620,gid=5 0 0
proc    /proc             proc    defaults        0 0
sysfs   /sys              sysfs   noauto          0 0
debugfs /sys/kernel/debug debugfs noauto          0 0
usbfs   /proc/bus/usb     usbfs   noauto          0 0
tmpfs   /run              tmpfs   noauto          0 0
/dev/disk/by-id/ata-QEMU_HARDDISK_QM00001-part1 / ext3 defaults 1 1
```

18.3.7 Converting a physical machine into a KVM guest

Libguestfs provides tools to help converting Xen virtual machines or physical machines into KVM guests. The following section covers a special use case: converting a bare metal machine into a KVM one.

Converting a physical machine into a KVM one is not yet supported in openSUSE Leap. This feature is released as a technology preview only.

Converting a physical machine requires collecting information about it and transmitting this to a conversion server. This is achieved by running a live system prepared with **`virt-p2v`** and KIWI tools on the machine.

PROCEDURE 18.2: USING VIRT-P2V

1. Install the needed packages with the command:

   ```
   > sudo zypper in virt-p2v kiwi-desc-isoboot
   ```

   ### Note

   These steps document how to create an ISO image to create a bootable DVD. Alternatively, you can create a PXE boot image instead; for more information about building PXE images with KIWI, see **`man virt-p2v-make-kiwi`**.

2. Create a KIWI configuration:

   ```
   > virt-p2v-make-kiwi -o /tmp/p2v.kiwi
   ```

   The `-o` defines where to create the KIWI configuration.

3. Edit the `config.xml` file in the generated configuration if needed. For example, in `config.xml` adjust the keyboard layout of the live system.

4. Build the ISO image with **`kiwi`**:

   ```
   > kiwi --build /tmp/p2v.kiwi❶ \
        -d /tmp/build❷ \
        --ignore-repos \
        --add-repo http://URL_TO_REPOSITORIES❸ \
        --type iso
   ```

   ❶ The directory where the KIWI configuration was generated in the previous step.

   ❷ The directory where KIWI will place the generated ISO image and other intermediary build results.

   ❸ The URLs to the package repositories as found with **`zypper lr -d`**.
   Use one `--add-repo` parameter per repository.

5. Burn the ISO on a DVD or a USB stick. With such a medium, boot the machine to be converted.

6. After the system is started, enter the connection details of the *conversion server*. This server is a machine with the `virt-v2v` package installed.
   If the network setup is more complex than a DHCP client, click the *Configure network* button to open the YaST network configuration dialog.
   Click the *Test connection* button to allow moving to the next page of the wizard.

7. Select the disks and network interfaces to be converted and define the VM data like the amount of allocated CPUs, memory and the Virtual Machine name.

   ### Note

   If not defined, the created disk image format is *raw* by default. This can be changed by entering the desired format in the *Output format* field.

   There are two possibilities to generate the virtual machine: either using the *local* or the *libvirt* output. The first one places the Virtual Machine disk image and configuration in the path defined in the *Output storage* field. These can then be used to define a new libvirt-handled guest using **`virsh`**. The second method creates a new libvirt-handled guest with the disk image placed in the pool defined in the *Output storage* field.
   Click *Start conversion* to start it.

18.4 Troubleshooting

18.4.1 Btrfs-related problems

When using the guestfs tools on an image with Btrfs root partition (the default with openSUSE Leap) the following error message may be displayed:

```
> virt-ls -a /path/to/sles12sp2.qcow2 /
virt-ls: multi-boot operating systems are not supported

If using guestfish '-i' option, remove this option and instead
use the commands 'run' followed by 'list-filesystems'.
You can then mount file systems you want by hand using the
'mount' or 'mount-ro' command.

If using guestmount '-i', remove this option and choose the
```

```
filesystem(s) you want to see by manually adding '-m' option(s).
Use 'virt-filesystems' to see what file systems are available.

If using other virt tools, multi-boot operating systems won't work
with these tools.  Use the guestfish equivalent commands
(see the virt tool manual page).
```

This is often caused by the presence of snapshots in the guests. In this case guestfs does not know which snapshot to bootstrap. To force the use of a snapshot, use the `-m` parameter as follows:

```
> virt-ls -m /dev/sda2:/:subvol=@/.snapshots/2/snapshot -a /path/to/sles12sp2.qcow2 /
```

18.4.2 Environment

When troubleshooting problems within a libguestfs appliance, the environment variable *LIBGUESTFS_DEBUG=1* can be used to enable debug messages. To output each command/API call in a format that is similar to guestfish commands, use the environment variable *LIBGUESTFS_TRACE=1*.

18.4.3 `libguestfs-test-tool`

`libguestfs-test-tool` is a test program that checks if basic libguestfs functionality is working. It prints a large amount of diagnostic messages and details of the guestfs environment, then create a test image and try to start it. If it runs to completion successfully, the following message should be seen near the end:

```
===== TEST FINISHED OK =====
```

18.5 More information

- libguestfs.org (https://libguestfs.org)
- libguestfs FAQ (https://libguestfs.org/guestfs-faq.1.html)

19 QEMU guest agent

The QEMU guest agent (GA) runs inside the VM Guest and allows the VM Host Server to run commands in the guest operating system via `libvirt`. It supports many functions—for example, getting details about guest file systems, freezing and thawing file systems, or suspending or rebooting a guest.

QEMU GA is included in the `qemu-guest-agent` package and is installed, configured and activated by default on KVM virtual machines.

QEMU GA is installed in Xen virtual machines, but it is not activated by default. Although it is possible to use QEMU GA with Xen virtual machines, there is no integration with libvirt as described below for KVM virtual machines. To use QEMU GA with Xen, a channel device must be added to the VM Guest configuration. The channel device includes a Unix domain socket path on the VM Host Server for communicating with QEMU GA.

```
<channel type='unix'>
  <source mode='bind' path='/example/path'/>
  <target type='xen' name='org.qemu.guest_agent.0'/>
</channel>
```

19.1 Running QEMU GA commands

QEMU GA includes many native commands that do not have direct `libvirt` counterparts. Refer to *Section 19.4, "More information"* to find the complete list. You can run all the QEMU GA commands by using `libvirt`'s general purpose command **`qemu-agent-command`**:

```
virsh qemu-agent-command DOMAIN_NAME '{"execute":"QEMU_GA_COMMAND"}'
```

For example:

```
> sudo virsh qemu-agent-command sle15sp2 '{"execute":"guest-info"}' --pretty
{
"return": {
  "version": "4.2.0",
  "supported_commands": [
    {
      "enabled": true,
      "name": "guest-get-osinfo",
      "success-response": true
    },
[...]
```

19.2 `virsh` commands that require QEMU GA

Several `virsh` commands require QEMU GA for their functionality. For example, the following ones:

`virsh guestinfo`

Prints information about the guest from the guest's point of view.

`virsh guestvcpus`

Queries or changes the state of virtual CPUs from the guest's point of view.

`virsh set-user-password`

Sets the password for a user account in the guest.

`virsh domfsinfo`

Shows a list of mounted file systems within the running domain.

`virsh dompmsuspend`

Suspends a running guest.

19.3 Enhancing `libvirt` commands

If QEMU GA is enabled inside the guest, several `virsh` subcommands have enhanced functionality when run in the *agent* mode. The following list includes only certain examples of them. For a complete list, see the `virsh` manual page and search for the `agent` string.

`virsh shutdown --mode agent` and `virsh reboot --mode agent`

This method of shutting down or rebooting leaves the guest clean for its next run, similar to the ACPI method.

`virsh domfsfreeze` and `virsh domfsthaw`

Instructs the guest to make its file system quiescent—to flush all I/O operations in the cache and leave volumes in a consistent state, so that no checks are needed when they are remounted.

`virsh setvcpus --guest`

Changes the number of CPUs assigned to a guest.

`virsh domifaddr --source agent`

Queries the QEMU GA for the guest's IP address.

`virsh vcpucount --guest`

Prints information about the virtual CPU counts from the perspective of the guest.

19.4 More information

- A complete list of commands supported by the QEMU GA is at https://www.qemu.org/docs/master/interop/qemu-ga-ref.html ↗.
- The `virsh` manual page (`man 1 virsh`) includes descriptions of the commands that support the QEMU GA interface.

20 Software TPM emulator

20.1 Introduction

The Trusted Platform Module (TPM) is a cryptoprocessor that secures hardware using cryptographic keys. For developers who use the TPM to develop security features, a software TPM emulator is a convenient solution. Compared to a hardware TPM device, the emulator has no limit on the number of guests that can access it. Also, it is simple to switch between TPM versions 1.2 and 2.0. QEMU supports the software TPM emulator that is included in the `swtpm` package.

20.2 Prerequisites

Before you can install and use the software TPM emulator, you need to install the `libvirt` virtualization environment. Refer to *Section 6.2, "Installing virtualization components"* and install one of the provided virtualization solutions.

20.3 Installation

To use the software TPM emulator, install the `swtpm` package:

```
> sudo zypper install swtpm
```

20.4 Using swtpm with QEMU

`swtpm` provides three types of interface: `socket`, `chardev`, and `cuse`. This procedure focuses on the *socket* interface.

1. Create a directory `mytpm0` inside the VM directory to store the TPM states—for example, `/var/lib/libvirt/qemu/sle15sp3`:

   ```
   > sudo mkdir /var/lib/libvirt/qemu/sle15sp3/mytpm0
   ```

2. Start **`swtmp`**. It creates a socket file that QEMU can use—for example, `/var/lib/libvirt/qemu/sle15sp3`:

```
> sudo swtpm socket
 --tpmstate dir=/var/lib/libvirt/qemu/sle15sp3/mytpm0 \
 --ctrl type=unixio,path=/var/lib/libvirt/qemu/sle15sp3/mytpm0/swtpm-sock \
 --log level=20
```

Tip: TPM version 2.0

By default, **`swtpm`** starts a TPM version 1.2 emulator and stores its states in the `tpm-00.permall` directory. To create a TPM 2.0 instance, run:

```
> sudo swtpm socket
 --tpm2
 --tpmstate dir=/var/lib/libvirt/qemu/sle15sp3/mytpm0 \
 --ctrl type=unixio,path=/var/lib/libvirt/qemu/sle15sp3/mytpm0/swtpm-sock \
 --log level=20
```

TPM 2.0 states are stored in the `tpm2-00.permall` directory.

3. Add the following command line parameters to the **`qemu-system-`*`ARCH`*** command:

```
> qemu-system-x86_64 \
[...]
-chardev socket,id=chrtpm,path=/var/lib/libvirt/qemu/sle15sp3/mytpm0/swtpm-sock \
-tpmdev emulator,id=tpm0,chardev=chrtpm \
-device tpm-tis,tpmdev=tpm0
```

4. Verify that the TPM device is available in the guest by running the following command:

```
> tpm_version
TPM 1.2 Version Info:
Chip Version:        1.2.18.158
Spec Level:          2
Errata Revision:     3
TPM Vendor ID:       IBM
TPM Version:         01010000
Manufacturer Info:   49424d00
```

20.5 Using swtpm with `libvirt`

To use swtpm with `libvirt`, add the following TPM device to the guest XML specification:

```
<devices>
 <tpm model='tpm-tis'>
  <backend type='emulator' version='2.0'/>
 </tpm>
</devices>
```

`libvirt` starts swtpm for the guest automatically. You do not need to start it manually in advance. The corresponding `permall` file is created in `/var/lib/libvirt/swtpm/VM_UUID`.

20.6 TPM measurement with OVMF firmware

If the guest uses the Open Virtual Machine Firmware (OVMF), it measures components with TPM. You can find the event log in `/sys/kernel/security/tpm0/binary_bios_measurements`.

20.7 Resources

- Wikipedia offers a thorough description of the TPM at the page https://en.wikipedia.org/wiki/Trusted_Platform_Module ↗.
- Configuring a specific virtualization environment on openSUSE Leap is described in *Chapter 6, Installation of virtualization components*.
- Details on the use of `swtpm` are on its manual page (**`man 8 swtpm`**).
- A detailed `libvirt` specification of TPM is at https://libvirt.org/formatdomain.html#elementsTpm ↗
- A description of enabling UEFI firmware by using OVMF is at *Section 6.3, “Installing UEFI support”*.

21 Creating crash dumps of a VM Guest

21.1 Introduction

Whenever a VM crashes, it is useful to collect a core dump of the VM memory for debugging and analysis. For physical machines, Kexec and Kdump takes care of collecting crash dumps. For virtual machines, it depends whether the guest is fully virtualized (FV) or paravirtualized (PV).

21.2 Creating crash dumps for fully virtualized machines

To view crash dumps for FV machines, use the same procedures as for physical machines—Kexec and Kdump.

21.3 Creating crash dumps for paravirtualized machines

Unlike with FVs, Kexec/Kdump does not work in paravirtualized machines. Crash dumps of PV guests must be performed by the host tool stack. If using the **`xl`** tool stack for Xen domUs, the **`xl dump-core`** command produces the dump. For `libvirt`-based VM Guests, the **`virsh dump`** command provides the same functionality.

You can configure automatic collection of a core dump with the `on_crash` setting in the configuration of the VM Guest. This setting tells the host tool stack what to do if the VM Guest encounters a crash. The default in both **`xl`** and `libvirt` is `destroy`. Useful options for automatically collecting a core dump are `coredump-destroy` and `coredump-restart`.

21.4 Additional information

- The difference between fully virtualized and paravirtualized virtual machines is described in *Section 1.3, “Virtualization modes”*.
- Detailed information about Kexec/Kdump mechanism is included in *Book* “System Analysis and Tuning Guide”, *Chapter 17 “Kexec and Kdump”*.
- Refer to the xl.cfg manual page (**`man 5 xl.cfg`**) for more information on the **`xl`** configuration syntax.
- Refer to https://libvirt.org/formatdomain.html#events-configuration for details about the `libvirt` XML settings.

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22 Setting up a virtual machine host

This section documents how to set up and use openSUSE Leap 15.5 as a virtual machine host.

The hardware requirements for the Dom0 are often the same as those for the openSUSE Leap operating system. Additional CPU, disk, memory and network resources should be added to accommodate the resource demands of all planned VM Guest systems.

Tip: Resources

Remember that VM Guest systems, like physical machines, perform better when they run on faster processors and have access to more system memory.

The virtual machine host requires several software packages and their dependencies to be installed. To install all necessary packages, run YaST *Software Management*, select *View* › *Patterns* and choose *Xen Virtual Machine Host Server* for installation. The installation can also be performed with YaST using the module *Virtualization* › *Install Hypervisor and Tools*.

After the Xen software is installed, restart the computer and, on the boot screen, choose the newly added option with the Xen kernel.

Updates are available through your update channel. To be sure to have the latest updates installed, run YaST *Online Update* after the installation has finished.

22.1 Best practices and suggestions

When installing and configuring the openSUSE Leap operating system on the host, be aware of the following best practices and suggestions:

- If the host should always run as Xen host, run YaST *System* › *Boot Loader* and activate the Xen boot entry as default boot section.

  - In YaST, click *System* > *Boot Loader*.
  - Change the default boot to the *Xen* label, then click *Set as Default*.
  - Click *Finish*.
- For best performance, only the applications and processes required for virtualization should be installed on the virtual machine host.
- If you intend to use a watchdog device attached to the Xen host, use only one at a time. It is recommended to use a driver with actual hardware integration over a generic software one.

Note: Hardware monitoring

The Dom0 kernel is running virtualized, so tools like **`irqbalance`** or **`lscpu`** do not reflect the real hardware characteristics.

Important: Trusted boot not supported by Xen

Trusted boot (Tboot) is not supported by Xen. To ensure that the Xen host boots correctly, verify that the *Enable Trusted Boot Support* option is deactivated in the GRUB 2 configuration dialog.

22.2 Managing Dom0 memory

In previous versions of openSUSE Leap, the default memory allocation scheme of a Xen host was to allocate all host physical memory to Dom0 and enable auto-ballooning. Memory was automatically ballooned from Dom0 when additional domains were started. This behavior has always been error prone and disabling it was strongly encouraged. Starting with openSUSE Leap 15.1, auto-ballooning has been disabled by default and Dom0 is given 10% of host physical memory + 1 GB. For example, on a host with 32 GB of physical memory, 4.2 GB of memory is allocated for Dom0.

The use of the `dom0_mem` Xen command line option in `/etc/default/grub` is still supported and encouraged. You can restore the old behavior by setting `dom0_mem` to the host physical memory size and enabling the `autoballoon` setting in `/etc/xen/xl.conf`.

Warning: Insufficient memory for Dom0

The amount of memory reserved for Dom0 is a function of the number of VM Guests running on the host since Dom0 provides back-end network and disk I/O services for each VM Guest. Other workloads running in Dom0 should also be considered when calculating Dom0 memory allocation. In general, memory sizing of Dom0 should be determined like any other virtual machine.

22.2.1 Setting Dom0 memory allocation

1. Determine memory allocation required for Dom0.

2. At Dom0, type **`xl info`** to view the amount of memory that is available on the machine. Dom0's current memory allocation can be determined with the **`xl list`** command.

3. Edit `/etc/default/grub` and adjust the `GRUB_CMDLINE_XEN` option so that it includes `dom0_mem=`*`MEM_AMOUNT`*. Replace *`MEM_AMOUNT`* with the maximum amount of memory to allocate to Dom0. Add **`K`**, **`M`**, or **`G`**, to specify the size unit. For example:

```
GRUB_CMDLINE_XEN="dom0_mem=2G"
```

4. Restart the computer to apply the changes.

Tip

Refer to *Book "Reference", Chapter 12 "The boot loader GRUB 2", Section 12.2.2 "The file `/etc/default/grub`"* for more details about Xen-related boot configuration options.

Warning: Xen Dom0 memory

When using the XL tool stack and the **`dom0_mem=`** option for the Xen hypervisor in GRUB 2 you need to disable xl *autoballoon* in `etc/xen/xl.conf`. Otherwise launching VMs fails with errors about not being able to balloon down Dom0. So add *autoballoon=0* to `xl.conf` if you have the **`dom0_mem=`** option specified for Xen. Also see Xen dom0 memory (http://wiki.xen.org/wiki/Xen_Best_Practices#Xen_dom0_dedicated_memory_and_preventing_dom0_memory_ballooning) ↗

22.3 Network card in fully virtualized guests

In a fully virtualized guest, the default network card is an emulated Realtek network card. However, it also possible to use the split network driver to run the communication between Dom0 and a VM Guest. By default, both interfaces are presented to the VM Guest, because the drivers of certain operating systems require both to be present.

When using openSUSE Leap, only the paravirtualized network cards are available for the VM Guest by default. The following network options are available:

emulated

To use an emulated network interface like an emulated Realtek card, specify `type=ioemu` in the `vif` device section of the domain xl configuration. An example configuration would look like:

```
vif = [ 'type=ioemu,mac=00:16:3e:5f:48:e4,bridge=br0' ]
```

Find more details about the xl configuration in the `xl.conf` manual page **`man 5 xl.conf`**.

paravirtualized

When you specify `type=vif` and do not specify a model or type, the paravirtualized network interface is used:

```
vif = [ 'type=vif,mac=00:16:3e:5f:48:e4,bridge=br0,backen=0' ]
```

emulated and paravirtualized

If the administrator should be offered both options, simply specify both type and model. The xl configuration would look like:

```
vif = [ 'type=ioemu,mac=00:16:3e:5f:48:e4,model=rtl8139,bridge=br0' ]
```

In this case, one of the network interfaces should be disabled on the VM Guest.

22.4 Starting the virtual machine host

If virtualization software is correctly installed, the computer boots to display the GRUB 2 boot loader with a *Xen* option on the menu. Select this option to start the virtual machine host.

Warning

When booting a Xen system, you may observe error messages in the /var/log/messages log file or `systemd` journal of dom0 similar to following:

```
isst_if_mbox_pci: probe of 0000:ff:1e.1 failed with error -5
isst_if_pci: probe of 0000:fe:00.1 failed with error -5
```

Ignore them as they are harmless and are caused by the fact that the ISST driver does not provide any power or frequency scaling feature for virtual machines.

Note: Xen and Kdump

In Xen, the hypervisor manages the memory resource. If you need to reserve system memory for a recovery kernel in Dom0, this memory need to be reserved by the hypervisor. Thus, it is necessary to add the parameter `crashkernel=size` to the `kernel` line instead of using the line with the other boot parameters.

For more information on the crashkernel parameter, see *Book* "System Analysis and Tuning Guide", *Chapter 17 "Kexec and Kdump", Section 17.4 "Calculating* `crashkernel` *allocation size"*.

If the *Xen* option is not on the GRUB 2 menu, review the steps for installation and verify that the GRUB 2 boot loader has been updated. If the installation has been done without selecting the Xen pattern, run the YaST *Software Management*, select the filter *Patterns* and choose *Xen Virtual Machine Host Server* for installation.

After booting the hypervisor, the Dom0 virtual machine starts and displays its graphical desktop environment. If you did not install a graphical desktop, the command line environment appears.

Tip: Graphics problems

Sometimes it may happen that the graphics system does not work properly. In this case, add `vga=ask` to the boot parameters. To activate permanent settings, use `vga=mode-0x???` where `???` is calculated as `0x100` + VESA mode from http://en.wikipedia.org/wiki/VESA_BIOS_Extensions ↗, for example `vga=mode-0x361`.

Before starting to install virtual guests, make sure that the system time is correct. To do this, configure NTP (Network Time Protocol) on the controlling domain:

1. In YaST select *Network Services* › *NTP Configuration*.

2. Select the option to automatically start the NTP daemon during boot. Provide the IP address of an existing NTP time server, then click *Finish*.

Note: Time services on virtual guests

Hardware clocks are not precise. All modern operating systems try to correct the system time compared to the hardware time bvia an additional time source. To get the correct time on all VM Guest systems, also activate the network time services on each respective guest or make sure that the guest uses the system time of the host. For more about `Independent Wallclocks` in openSUSE Leap see *Section 17.2, "Xen virtual machine clock settings"*.

For more information about managing virtual machines, see *Chapter 24, Managing a virtualization environment*.

22.5 PCI Pass-Through

To take full advantage of VM Guest systems, it is sometimes necessary to assign specific PCI devices to a dedicated domain. When using fully virtualized guests, this functionality is only available if the chipset of the system supports this feature, and if it is activated from the BIOS.

This feature is available from both AMD* and Intel*. For AMD machines, the feature is called *IOMMU*. In Intel speak, this is *VT-d*. Be aware that Intel-VT technology is not sufficient to use this feature for fully virtualized guests. To make sure that your computer supports this feature, ask your supplier specifically to deliver a system that supports PCI Pass-Through.

LIMITATIONS

- Some graphics drivers use highly optimized ways to access DMA. This is not supported, and thus using graphics cards may be difficult.

- When accessing PCI devices behind a *PCIe* bridge, all the PCI devices must be assigned to a single guest. This limitation does not apply to *PCIe* devices.

- Guests with dedicated PCI devices cannot be migrated live to a different host.

The configuration of PCI Pass-Through is twofold. First, the hypervisor must be informed at boot time that a PCI device should be available for reassigning. Second, the PCI device must be assigned to the VM Guest.

22.5.1 Configuring the hypervisor for PCI Pass-Through

1. Select a device to reassign to a VM Guest. To do this, run **`lspci -k`**, and read the device number and the name of the original module that is assigned to the device:

   ```
   06:01.0 Ethernet controller: Intel Corporation Ethernet Connection I217-LM (rev 05)
           Subsystem: Dell Device 0617
           Kernel driver in use: e1000e
           Kernel modules: e1000e
   ```

   In this case, the PCI number is `(06:01.0)` and the dependent kernel module is `e1000e`.

2. Specify a module dependency to ensure that `xen_pciback` is the first module to control the device. Add the file named `/etc/modprobe.d/50-e1000e.conf` with the following content:

   ```
   install e1000e /sbin/modprobe xen_pciback ; /sbin/modprobe \
    --first-time --ignore-install e1000e
   ```

3. Instruct the `xen_pciback` module to control the device using the `hide` option. Edit or create `/etc/modprobe.d/50-xen-pciback.conf` with the following content:

   ```
   options xen_pciback hide=(06:01.0)
   ```

4. Reboot the system.

5. Check if the device is in the list of assignable devices with the command

   ```
   xl pci-assignable-list
   ```

22.5.1.1 Dynamic assignment with xl

To avoid restarting the host system, you can use dynamic assignment with xl to use PCI Pass-Through.

Begin by making sure that dom0 has the pciback module loaded:

```
> sudo modprobe pciback
```

Then make a device assignable by using **`xl pci-assignable-add`**. For example, to make the device *06:01.0* available for guests, run the command:

```
> sudo xl pci-assignable-add 06:01.0
```

22.5.2 Assigning PCI devices to VM Guest systems

There are several possibilities to dedicate a PCI device to a VM Guest:

Adding the device while installing:

During installation, add the `pci` line to the configuration file:

```
pci=['06:01.0']
```

Hotplugging PCI devices to VM Guest systems

The command `xl` can be used to add or remove PCI devices on the fly. To add the device with number `06:01.0` to a guest with name `sles12` use:

```
xl pci-attach sles12 06:01.0
```

Adding the PCI device to Xend

To add the device to the guest permanently, add the following snippet to the guest configuration file:

```
pci = [ '06:01.0,power_mgmt=1,permissive=1' ]
```

After assigning the PCI device to the VM Guest, the guest system must care for the configuration and device drivers for this device.

22.5.3 VGA Pass-Through

Xen 4.0 and newer supports VGA graphics adapter pass-through on fully virtualized VM Guests. The guest can take full control of the graphics adapter with high-performance full 3D and video acceleration.

LIMITATIONS

- VGA Pass-Through functionality is similar to PCI Pass-Through and as such also requires *IOMMU* (or Intel VT-d) support from the mainboard chipset and BIOS.
- Only the primary graphics adapter (the one that is used when you power on the computer) can be used with VGA Pass-Through.
- VGA Pass-Through is supported only for fully virtualized guests. Paravirtual guests (PV) are not supported.
- The graphics card cannot be shared between multiple VM Guests using VGA Pass-Through — you can dedicate it to one guest only.

To enable VGA Pass-Through, add the following settings to your fully virtualized guest configuration file:

```
gfx_passthru=1
pci=['yy:zz.n']
```

where `yy:zz.n` is the PCI controller ID of the VGA graphics adapter as found with **`lspci -v`** on Dom0.

22.5.4 Troubleshooting

In certain circumstances, problems may occur during the installation of the VM Guest. This section describes several known problems and their solutions.

During boot, the system hangs

The software I/O translation buffer allocates a large chunk of low memory early in the bootstrap process. If the requests for memory exceed the size of the buffer, it may result in a hung boot process. To check if this is the case, switch to console 10 and check the output there for a message similar to

```
kernel: PCI-DMA: Out of SW-IOMMU space for 32768 bytes at device 000:01:02.0
```

In this case you need to increase the size of the `swiotlb`. Add `swiotlb=`*`VALUE`* (where *`VALUE`* is specified as the number of slab entries) on the command line of Dom0. The number can be adjusted up or down to find the optimal size for the machine.

Note: swiotlb a PV guest

The `swiotlb=force` kernel parameter is required for DMA access to work for PCI devices on a PV guest. For more information about IOMMU and the `swiotlb` option see the file `boot-options.txt` from the package `kernel-source`.

22.5.5 More information

There are several resources on the Internet that provide interesting information about PCI Pass-Through:

- https://wiki.xenproject.org/wiki/VTd_HowTo
- http://software.intel.com/en-us/articles/intel-virtualization-technology-for-directed-io-vt-d-enhancing-intel-platforms-for-efficient-virtualization-of-io-devices/
- http://support.amd.com/TechDocs/48882_IOMMU.pdf

22.6 USB pass-through

There are two methods for passing through individual host USB devices to a guest. The first is via an emulated USB device controller, the second is using PVUSB.

22.6.1 Identify the USB device

Before you can pass through a USB device to the VM Guest, you need to identify it on the VM Host Server. Use the **`lsusb`** command to list the USB devices on the host system:

```
# lsusb
Bus 001 Device 001: ID 1d6b:0002 Linux Foundation 2.0 root hub
Bus 002 Device 003: ID 0461:4d15 Primax Electronics, Ltd Dell Optical Mouse
Bus 002 Device 001: ID 1d6b:0001 Linux Foundation 1.1 root hub
```

To pass through the Dell mouse, for example, specify either the device tag in the form `vendor_id:device_id` (0461:4d15) or the bus address in the form `bus.device` (2.3). Remember to remove leading zeros, otherwise **`xl`** would interpret the numbers as octal values.

22.6.2 Emulated USB device

In emulated USB, the device model (QEMU) presents an emulated USB controller to the guest. The USB device is then controlled from Dom0 while USB commands are translated between the VM Guest and the host USB device. This method is only available to fully virtualized domains (HVM).

Enable the emulated USB hub with the `usb=1` option. Then specify devices among the list of devices in the configuration file along with other emulated devices by using `host:USBID`. For example:

```
usb=1
usbdevice=['tablet','host:2.3','host:0424:460']
```

22.6.3 Paravirtualized PVUSB

PVUSB is a new high performance method for USB Pass-Through from dom0 to the virtualized guests. With PVUSB, there are two ways to add USB devices to a guest:

- via the configuration file at domain creation time
- via hotplug while the VM is running

PVUSB uses paravirtualized front- and back-end interfaces. PVUSB supports USB 1.1 and USB 2.0, and it works for both PV and HVM guests. To use PVUSB, you need usbfront in your guest OS, and usbback in dom0 or usb back-end in qemu. On openSUSE Leap, the USB back-end comes with qemu.

As of Xen 4.7, **`xl`** PVUSB support and hotplug support is introduced.

In the configuration file, specify USB controllers and USB host devices with `usbctrl` and `usbdev`. For example, in case of HVM guests:

```
usbctrl=['type=qusb,version=2,ports=4', 'type=qusb,version=1,ports=4', ]
usbdev=['hostbus=2, hostaddr=1, controller=0,port=1', ]
```

Note

It is important to specify `type=qusb` for the controller of HVM guests.

To manage hotpluggin PVUSB devices, use the `usbctrl-attach`, `usbctrl-detach`, `usb-list`, `usbdev-attach` and `usb-detach` subcommands. For example:

Create a USB controller which is version USB 1.1 and has 8 ports:

```
# xl usbctrl-attach test_vm version=1 ports=8 type=qusb
```

Find the first available controller:port in the domain, and attach USB device whose busnum:devnum is 2:3 to it; you can also specify `controller` and `port`:

```
# xl usbdev-attach test_vm hostbus=2 hostaddr=3
```

Show all USB controllers and USB devices in the domain:

```
# xl usb-list test_vm
Devid  Type   BE  state usb-ver ports
0      qusb   0   1     1       8
  Port 1: Bus 002 Device 003
  Port 2:
  Port 3:
  Port 4:
  Port 5:
  Port 6:
  Port 7:
  Port 8:
```

Detach the USB device under controller 0 port 1:

```
# xl usbdev-detach test_vm 0 1
```

Remove the USB controller with the indicated `dev_id`, and all USB devices under it:

```
# xl usbctrl-detach test_vm dev_id
```

For more information, see https://wiki.xenproject.org/wiki/Xen_USB_Passthrough ↗.

23 Virtual networking

A VM Guest system needs specific means to communicate either with other VM Guest systems or with a local network. The network interface to the VM Guest system is made of a split device driver, which means that any virtual Ethernet device has a corresponding network interface in Dom0. This interface is set up to access a virtual network that is run in Dom0. The bridged virtual network is fully integrated into the system configuration of openSUSE Leap and can be configured with YaST.

When installing a Xen VM Host Server, a bridged network configuration is proposed during normal network configuration. The user can choose to change the configuration during the installation and customize it to the local needs.

If desired, Xen VM Host Server can be installed after performing a default Physical Server installation using the `Install Hypervisor and Tools` module in YaST. This module prepares the system for hosting virtual machines, including invocation of the default bridge networking proposal.

In case the necessary packages for a Xen VM Host Server are installed manually with `rpm` or `zypper`, the remaining system configuration needs to be done by the administrator manually or with YaST.

The network scripts that are provided by Xen are not used by default in openSUSE Leap. They are only delivered for reference but disabled. The network configuration that is used in openSUSE Leap is done by means of the YaST system configuration similar to the configuration of network interfaces in openSUSE Leap.

For more general information about managing network bridges, see *Section 8.1.1, “Network bridge”*.

23.1 Network devices for guest systems

The Xen hypervisor can provide different types of network interfaces to the VM Guest systems. The preferred network device should be a paravirtualized network interface. This yields the highest transfer rates with the lowest system requirements. Up to eight network interfaces may be provided for each VM Guest.

Systems that are not aware of paravirtualized hardware may not have this option. To connect systems to a network that can only run fully virtualized, several emulated network interfaces are available. The following emulations are at your disposal:

- Realtek 8139 (PCI). This is the default emulated network card.
- AMD PCnet32 (PCI)
- NE2000 (PCI)
- NE2000 (ISA)
- Intel e100 (PCI)
- Intel e1000 and its variants e1000-82540em, e1000-82544gc, e1000-82545em (PCI)

All these network interfaces are software interfaces. Because every network interface must have a unique MAC address, an address range has been assigned to Xensource that can be used by these interfaces.

Tip: Virtual network interfaces and MAC addresses

The default configuration of MAC addresses in virtualized environments creates a random MAC address that looks like 00:16:3E:xx:xx:xx. Normally, the amount of available MAC addresses should be big enough to get only unique addresses. However, if you have a large installation, or to make sure that no problems arise from random MAC address assignment, you can also manually assign these addresses.

For debugging or system management purposes, it may be useful to know which virtual interface in Dom0 is connected to which Ethernet device in a running guest. This information may be read from the device naming in Dom0. All virtual devices follow the rule `vif<domain number>.<interface_number>`.

For example, to know the device name for the third interface (eth2) of the VM Guest with id 5, the device in Dom0 would be `vif5.2`. To obtain a list of all available interfaces, run the command **`ip a`**.

The device naming does not contain any information about which bridge this interface is connected to. However, this information is available in Dom0. To get an overview about which interface is connected to which bridge, run the command **`bridge link`**. The output may look as follows:

```
> sudo bridge link
2: eth0 state DOWN : <NO-CARRIER,BROADCAST,MULTICAST,SLAVE,UP> mtu 1500 master br0
3: eth1 state UP : <BROADCAST,MULTICAST,SLAVE,UP,LOWER_UP> mtu 1500 master br1
```

In this example, there are three configured bridges: `br0`, `br1` and `br2`. Currently, `br0` and `br1` each have a real Ethernet device added: `eth0` and `eth1`, respectively.

23.2 Host-based routing in Xen

Xen can be set up to use host-based routing in the controlling Dom0, although this is not yet well supported from YaST and requires certain amount of manual editing of configuration files. Thus, this is a task that requires an advanced administrator.

The following configuration only works when using fixed IP addresses. Using DHCP is not practicable with this procedure, because the IP address must be known to both the VM Guest and the VM Host Server system.

The easiest way to create a routed guest is to change the networking from a bridged to a routed network. As a requirement to the following procedures, a VM Guest with a bridged network setup must be installed. For example, the VM Host Server is named earth with the IP 192.168.1.20, and the VM Guest has the name alice with the IP 192.168.1.21.

PROCEDURE 23.1: CONFIGURING A ROUTED IPV4 VM GUEST

1. Make sure that alice is shut down. Use `xl` commands to shut down and check.

2. Prepare the network configuration on the VM Host Server earth:

   a. Create a hotplug interface to route the traffic. To accomplish this, create a file named `/etc/sysconfig/network/ifcfg-alice.0` with the following content:

      ```
      NAME="Xen guest alice"
      BOOTPROTO="static"
      STARTMODE="hotplug"
      ```

b. Ensure that IP forwarding is enabled:

   i. In YaST, go to *Network Settings* › *Routing*.

   ii. Enter the *Routing* tab and activate *Enable IPv4 Forwarding* and *Enable IPv6 Forwarding* options.

   iii. Confirm the setting and quit YaST.

c. Apply the following configuration to `firewalld`:

   - Add alice.0 to the devices in the public zone:

     ```
     > sudo firewall-cmd --zone=public --add-interface=alice.0
     ```

   - Tell the firewall which address should be forwarded:

     ```
     > sudo firewall-cmd --zone=public \
     --add-forward-
     port=port=80:proto=tcp:toport=80:toaddr="192.168.1.21/32,0/0"
     ```

   - Make the runtime configuration changes permanent:

     ```
     > sudo firewall-cmd --runtime-to-permanent
     ```

d. Add a static route to the interface of alice. To accomplish this, add the following line to the end of `/etc/sysconfig/network/routes`:

   ```
   192.168.1.21   -   -   alice.0
   ```

e. To make sure that the switches and routers that the VM Host Server is connected to know about the routed interface, activate `proxy_arp` on earth. Add the following lines to `/etc/sysctl.conf`:

   ```
   net.ipv4.conf.default.proxy_arp = 1
   net.ipv4.conf.all.proxy_arp = 1
   ```

f. Activate all changes with the commands:

   ```
   > sudo systemctl restart systemd-sysctl wicked
   ```

3. Proceed with configuring the Xen configuration of the VM Guest by changing the vif interface configuration for alice as described in *Section 24.1, “XL—Xen management tool”*. Make the following changes to the text file you generate during the process:

    a. Remove the snippet

    ```
    bridge=br0
    ```

    b. And add the following one:

    ```
    vifname=vifalice.0
    ```

    or

    ```
    vifname=vifalice.0=emu
    ```

    for a fully virtualized domain.

    c. Change the script that is used to set up the interface to the following:

    ```
    script=/etc/xen/scripts/vif-route-ifup
    ```

    d. Activate the new configuration and start the VM Guest.

4. The remaining configuration tasks must be accomplished from inside the VM Guest.

    a. Open a console to the VM Guest with `**xl console** *DOMAIN*` and log in.

    b. Check that the guest IP is set to 192.168.1.21.

    c. Provide VM Guest with a host route and a default gateway to the VM Host Server. Do this by adding the following lines to `/etc/sysconfig/network/routes`:

    ```
    192.168.1.20 - - eth0
    default 192.168.1.20 - -
    ```

5. Finally, test the network connection from the VM Guest to the world outside and from the network to your VM Guest.

23.3 Creating a masqueraded network setup

Creating a masqueraded network setup is similar to the routed setup. However, there is no proxy_arp needed, and certain firewall rules are different. To create a masqueraded network to a guest dolly with the IP address 192.168.100.1 where the host has its external interface on `br0`, proceed as follows. For easier configuration, only the already installed guest is modified to use a masqueraded network:

PROCEDURE 23.2: CONFIGURING A MASQUERADED IPV4 VM GUEST

1. Shut down the VM Guest system with **`xl shutdown`** *`DOMAIN`*.

2. Prepare the network configuration on the VM Host Server:

   a. Create a hotplug interface to route the traffic. To accomplish this, create a file named `/etc/sysconfig/network/ifcfg-dolly.0` with the following content:

   ```
   NAME="Xen guest dolly"
   BOOTPROTO="static"
   STARTMODE="hotplug"
   ```

   b. Edit the file `/etc/sysconfig/SuSEfirewall2` and add the following configurations:

      - Add dolly.0 to the devices in FW_DEV_DMZ:

        ```
        FW_DEV_DMZ="dolly.0"
        ```

      - Switch on the routing in the firewall:

        ```
        FW_ROUTE="yes"
        ```

      - Switch on masquerading in the firewall:

        ```
        FW_MASQUERADE="yes"
        ```

      - Tell the firewall which network should be masqueraded:

        ```
        FW_MASQ_NETS="192.168.100.1/32"
        ```

- Remove the networks from the masquerading exceptions:

```
FW_NOMASQ_NETS=""
```

- Finally, restart the firewall with the command:

```
> sudo systemctl restart SuSEfirewall2
```

c. Add a static route to the interface of dolly. To accomplish this, add the following line to the end of `/etc/sysconfig/network/routes`:

```
192.168.100.1 - - dolly.0
```

d. Activate all changes with the command:

```
> sudo systemctl restart wicked
```

3. Proceed with configuring the Xen configuration of the VM Guest.

a. Change the vif interface configuration for dolly as described in *Section 24.1, "XL—Xen management tool"*.

b. Remove the entry:

```
bridge=br0
```

c. And add the following one:

```
vifname=vifdolly.0
```

d. Change the script that is used to set up the interface to the following:

```
script=/etc/xen/scripts/vif-route-ifup
```

e. Activate the new configuration and start the VM Guest.

4. The remaining configuration tasks need to be accomplished from inside the VM Guest.

a. Open a console to the VM Guest with **`xl console`** *`DOMAIN`* and log in.

b. Check whether the guest IP is set to 192.168.100.1.

c. Provide VM Guest with a host route and a default gateway to the VM Host Server. Do this by adding the following lines to `/etc/sysconfig/network/routes`:

```
192.168.1.20 - - eth0
default 192.168.1.20 - -
```

5. Finally, test the network connection from the VM Guest to the outside world.

23.4 Special configurations

There are many network configuration possibilities available to Xen. The following configurations are not activated by default:

23.4.1 Bandwidth throttling in virtual networks

With Xen, you may limit the network transfer rate a virtual guest may use to access a bridge. To configure this, you need to modify the VM Guest configuration as described in *Section 24.1, "XL—Xen management tool"*.

In the configuration file, first search for the device that is connected to the virtual bridge. The configuration looks like the following:

```
vif = [ 'mac=00:16:3e:4f:94:a9,bridge=br0' ]
```

To add a maximum transfer rate, add a parameter `rate` to this configuration as in:

```
vif = [ 'mac=00:16:3e:4f:94:a9,bridge=br0,rate=100Mb/s' ]
```

The rate is either `Mb/s` (megabits per second) or `MB/s` (megabytes per second). In the above example, the maximum transfer rate of the virtual interface is 100 megabits. By default, there is no limitation to the bandwidth of a guest to the virtual bridge.

It is even possible to fine-tune the behavior by specifying the time window that is used to define the granularity of the credit replenishment:

```
vif = [ 'mac=00:16:3e:4f:94:a9,bridge=br0,rate=100Mb/s@20ms' ]
```

23.4.2 Monitoring the network traffic

To monitor the traffic on a specific interface, the little application `iftop` is a nice program that displays the current network traffic in a terminal.

When running a Xen VM Host Server, you need to define the interface that is monitored. The interface that Dom0 uses to get access to the physical network is the bridge device, for example `br0`. This, however, may vary on your system. To monitor all traffic to the physical interface, run a terminal as `root` and use the command:

```
iftop -i br0
```

To monitor the network traffic of a special network interface of a specific VM Guest, supply the correct virtual interface. For example, to monitor the first Ethernet device of the domain with id 5, use the command:

```
ftop -i vif5.0
```

To quit **`iftop`**, press the key `Q`. More options and possibilities are available in the manual page **`man 8 iftop`**.

24 Managing a virtualization environment

Apart from using the recommended `libvirt` library (*Part II, “Managing virtual machines with `libvirt`”*), you can manage Xen guest domains with the **`xl`** tool from the command line.

24.1 XL—Xen management tool

The **`xl`** program is a tool for managing Xen guest domains. It is part of the `xen-tools` package. **`xl`** is based on the LibXenlight library, and can be used for general domain management, such as domain creation, listing, pausing or shutting down. You need to be `root` to execute **`xl`** commands.

Note

`xl` can only manage running guest domains specified by their configuration file. If a guest domain is not running, you cannot manage it with **`xl`**.

Tip

To allow users to continue to have managed guest domains in the way the obsolete **`xm`** command allowed, we now recommend using `libvirt`'s **`virsh`** and **`virt-manager`** tools. For more information, see *Part II, “Managing virtual machines with `libvirt`”*.

`xl` operations rely upon `xenstored` and `xenconsoled` services. Make sure you start

```
> systemctl start xencommons
```

at boot time to initialize all the daemons required by **`xl`**.

Tip: Set up a `xenbr0` network bridge in the host domain

In the most common network configuration, you need to set up a bridge in the host domain named `xenbr0` to have a working network for the guest domains.

The basic structure of every **`xl`** command is:

```
xl <subcommand> [options] domain_id
```

where <subcommand> is the xl command to run, domain_id is the ID number assigned to a domain or the name of the virtual machine, and **`OPTIONS`** indicates subcommand-specific options.

For a complete list of the available **`xl`** subcommands, run **`xl help`**. For each command, there is a more detailed help available that is obtained with the extra parameter `--help`. More information about the respective subcommands is available in the manual page of **`xl`**.

For example, the **`xl list --help`** displays all options that are available to the list command. As an example, the **`xl list`** command displays the status of all virtual machines.

```
> sudo xl list
Name                                  ID    Mem VCPUs       State   Time(s)
Domain-0                               0    457     2      r-----    2712.9
sles12                                 7    512     1      -b----      16.3
opensuse                                    512     1                  12.9
```

The *State* information indicates if a machine is running, and in which state it is. The most common flags are `r` (running) and `b` (blocked) where blocked means it is either waiting for IO, or sleeping because there is nothing to do. For more details about the state flags, see **`man 1 xl`**.

Other useful **`xl`** commands include:

- **`xl create`** creates a virtual machine from a given configuration file.
- **`xl reboot`** reboots a virtual machine.
- **`xl destroy`** immediately terminates a virtual machine.
- **`xl block-list`** displays all virtual block devices attached to a virtual machine.

24.1.1 Guest domain configuration file

When operating domains, **`xl`** requires a domain configuration file for each domain. The default directory to store such configuration files is `/etc/xen/`.

A domain configuration file is a plain text file. It consists of several *`KEY`* = *`VALUE`* pairs. Certain keys are mandatory. General keys apply to any guest, and specific ones apply only to a specific guest type (para or fully virtualized). A value can either be a `"string"` surrounded by single or double quotes, a number, a boolean value, or a list of several values enclosed in brackets `[ value1, value2, ... ]`.

EXAMPLE 24.1: GUEST DOMAIN CONFIGURATION FILE FOR SLED 12: `/etc/xen/sled12.cfg`

```
name= "sled12"
```

```
builder = "hvm"
vncviewer = 1
memory = 512
disk = [ '/var/lib/xen/images/sled12.raw,,hda', '/dev/cdrom,,hdc,cdrom' ]
vif = [ 'mac=00:16:3e:5f:48:e4,model=rtl8139,bridge=br0' ]
boot = "n"
```

To start such domain, run **`xl create /etc/xen/sled12.cfg`**.

24.2 Automatic start of guest domains

To make a guest domain start automatically after the host system boots, follow these steps:

1. Create the domain configuration file if it does not exist, and save it in the `/etc/xen/` directory, for example `/etc/xen/domain_name.cfg`.
2. Make a symbolic link of the guest domain configuration file in the `auto/` subdirectory.

   ```
   > sudo ln -s /etc/xen/domain_name.cfg /etc/xen/auto/domain_name.cfg
   ```

3. On the next system boot, the guest domain defined in `domain_name.cfg` is started.

24.3 Event actions

In the guest domain configuration file, you can define actions to be performed on a predefined set of events. For example, to tell the domain to restart itself after it is powered off, include the following line in its configuration file:

```
on_poweroff="restart"
```

A list of predefined events for a guest domain follows:

LIST OF EVENTS

on_poweroff

Specifies what should be done with the domain if it shuts itself down.

on_reboot

Action to take if the domain shuts down with a reason code requesting a reboot.

on_watchdog

Action to take if the domain shuts down because of a Xen watchdog timeout.

on_crash

Action to take if the domain crashes.

For these events, you can define one of the following actions:

LIST OF RELATED ACTIONS

destroy

Destroy the domain.

restart

Destroy the domain and immediately create a new domain with the same configuration.

rename-restart

Rename the domain that terminated, and then immediately create a new domain with the same configuration as the original.

preserve

Keep the domain. It can be examined, and later destroyed with **`xl destroy`**.

coredump-destroy

Write a core dump of the domain to `/var/xen/dump/NAME` and then destroy the domain.

coredump-restart

Write a core dump of the domain to `/var/xen/dump/NAME` and then restart the domain.

24.4 Time Stamp Counter

The Time Stamp Counter (TSC) may be specified for each domain in the guest domain configuration file (for more information, see *Section 24.1.1, "Guest domain configuration file"*).

With the `tsc_mode` setting, you specify whether rdtsc instructions are executed "natively" (fast, but TSC-sensitive applications may sometimes run incorrectly) or emulated (always run correctly, but performance may suffer).

`tsc_mode=0` (default)

Use this to ensure correctness while providing the best performance possible—for more information, see https://xenbits.xen.org/docs/4.3-testing/misc/tscmode.txt.

`tsc_mode=1` **(always emulate)**

Use this when TSC-sensitive apps are running and worst-case performance degradation is known and acceptable.

`tsc_mode=2` **(never emulate)**

Use this when all applications running in this VM are TSC-resilient and highest performance is required.

`tsc_mode=3` **(PVRDTSCP)**

High-TSC-frequency applications may be paravirtualized (modified) to obtain both correctness and highest performance—any unmodified applications must be TSC-resilient.

For background information, see https://xenbits.xen.org/docs/4.3-testing/misc/tscmode.txt ↗.

24.5 Saving virtual machines

PROCEDURE 24.1: SAVE A VIRTUAL MACHINE'S CURRENT STATE

1. Make sure the virtual machine to be saved is running.

2. In the host environment, enter

```
> sudo xl save ID STATE-FILE
```

where *`ID`* is the virtual machine ID you want to save, and *`STATE-FILE`* is the name you specify for the memory state file. By default, the domain is no longer running after you create its snapshot. Use `-c` to keep it running even after you create the snapshot.

24.6 Restoring virtual machines

PROCEDURE 24.2: RESTORE A VIRTUAL MACHINE'S CURRENT STATE

1. Make sure the virtual machine to be restored has not been started since you ran the save operation.

2. In the host environment, enter

```
> sudo xl restore STATE-FILE
```

> where *`STATE-FILE`* is the previously saved memory state file. By default, the domain is running after it is restored. To pause it after the restore, use `-p`.

24.7 Virtual machine states

A virtual machine's state can be displayed by viewing the results of the **`xl list`** command, which abbreviates the state using a single character.

- **`r`** - running - The virtual machine is currently running and consuming allocated resources.
- **`b`** - blocked - The virtual machine's processor is not running and not able to run. It is either waiting for I/O or has stopped working.
- **`p`** - paused - The virtual machine is paused. It does not interact with the hypervisor but still maintains its allocated resources, such as memory.
- **`s`** - shutdown - The guest operating system is in the process of being shut down, rebooted, or suspended, and the virtual machine is being stopped.
- **`c`** - crashed - The virtual machine has crashed and is not running.
- **`d`** - dying - The virtual machine is shutting down or crashing.

25 Block devices in Xen

25.1 Mapping physical storage to virtual disks

The disk specification for a Xen domain in the domain configuration file is as straightforward as the following example:

```
disk = [ 'format=raw,vdev=hdc,access=ro,devtype=cdrom,target=/root/image.iso' ]
```

It defines a disk block device based on the `/root/image.iso` disk image file. The is seen as `hdc` by the guest, with read-only (`ro`) access. The type of the device is `cdrom` with `raw` format.

The following example defines an identical device, but using simplified positional syntax:

```
disk = [ '/root/image.iso,raw,hdc,ro,cdrom' ]
```

You can include more disk definitions in the same line, each one separated by a comma. If a parameter is not specified, then its default value is taken:

```
disk = [ '/root/image.iso,raw,hdc,ro,cdrom','/dev/vg/guest-volume,,hda','...' ]
```

LIST OF PARAMETERS

target

Source block device or disk image path.

format

The format of the image file. Default is `raw`.

vdev

Virtual device as seen by the guest. Supported values are hd[x], xvd[x], sd[x] etc. See `/usr/share/doc/packages/xen/misc/vbd-interface.txt` for more details. This parameter is mandatory.

access

Whether the block device is provided to the guest in read-only or read-write mode. Supported values are `ro` or `r` for read-only, and `rw` or `w` for read/write access. Default is `ro` for `devtype=cdrom`, and `rw` for other device types.

devtype

Qualifies virtual device type. Supported value is `cdrom`.

backendtype

The back-end implementation to use. Supported values are `phy`, `tap`, and `qdisk`. Normally this option should not be specified as the back-end type is automatically determined.

script

Specifies that `target` is not a normal host path, but rather information to be interpreted by the executable program. The specified script file is looked for in `/etc/xen/scripts` if it does not point to an absolute path. These scripts are normally called `block-<script_name>`.

For more information about specifying virtual disks, see `/usr/share/doc/packages/xen/misc/xl-disk-configuration.txt`.

25.2 Mapping network storage to virtual disk

Similar to mapping a local disk image (see *Section 25.1, "Mapping physical storage to virtual disks"*), you can map a network disk as a virtual disk as well.

The following example shows mapping of an RBD (RADOS Block Device) disk with multiple Ceph monitors and cephx authentication enabled:

```
disk = [ 'vdev=hdc, backendtype=qdisk, \
target=rbd:libvirt-pool/new-libvirt-image:\
id=libvirt:key=AQDsPWtW8JoXJBAAyLPQe7MhCC+JPkI3QuhaAw==:auth_supported=cephx;none:\
mon_host=137.65.135.205\\:6789;137.65.135.206\\:6789;137.65.135.207\\:6789' ]
```

Following is an example of an NBD (Network Block Device) disk mapping:

```
disk = [ 'vdev=hdc, backendtype=qdisk, target=nbd:151.155.144.82:5555' ]
```

25.3 File-backed virtual disks and loopback devices

When a virtual machine is running, each of its file-backed virtual disks consumes a loopback device on the host. By default, the host allows up to 64 loopback devices to be consumed.

To simultaneously run more file-backed virtual disks on a host, you can increase the number of available loopback devices by adding the following option to the host's `/etc/modprobe.conf.local` file.

```
options loop max_loop=x
```

where `x` is the maximum number of loopback devices to create.

Changes take effect after the module is reloaded.

Tip

Enter **`rmmod loop`** and **`modprobe loop`** to unload and reload the module. In case **`rmmod`** does not work, unmount all existing loop devices or reboot the computer.

25.4 Resizing block devices

While it is always possible to add new block devices to a VM Guest system, it is sometimes more desirable to increase the size of an existing block device. In case such a system modification is already planned during deployment of the VM Guest, several basic considerations should be done:

- Use a block device that may be increased in size. LVM devices and file system images are commonly used.
- Do not partition the device inside the VM Guest, but use the main device directly to apply the file system. For example, use `/dev/xvdb` directly instead of adding partitions to `/dev/xvdb`.
- Make sure that the file system to be used can be resized. Sometimes, for example with Ext3, certain features must be switched off to be able to resize the file system. A file system that can be resized online and mounted is `XFS`. Use the command **`xfs_growfs`** to resize that file system after the underlying block device has been increased in size. For more information about `XFS`, see **`man 8 xfs_growfs`**.

When resizing an LVM device that is assigned to a VM Guest, the new size is automatically known to the VM Guest. No further action is needed to inform the VM Guest about the new size of the block device.

When using file system images, a loop device is used to attach the image file to the guest. For more information about resizing that image and refreshing the size information for the VM Guest, see *Section 27.2, “Sparse image files and disk space”*.

25.5 Scripts for managing advanced storage scenarios

There are scripts that can help with managing advanced storage scenarios such as disk environments provided by **`dmmd`** (“device mapper—multi disk”) including LVM environments built upon a software RAID set, or a software RAID set built upon an LVM environment. These scripts are part of the `xen-tools` package. After installation, they can be found in `/etc/xen/scripts`:

- **`block-dmmd`**
- **`block-drbd-probe`**
- **`block-npiv`**

The scripts allow for external commands to perform specific action, or series of actions of the block devices before serving them up to a guest.

These scripts could formerly only be used with **`xl`** or **`libxl`** using the disk configuration syntax `script=`. They can now be used with libvirt by specifying the base name of the block script in the `<source>` element of the disk. For example:

```
<source dev='dmmd:md;/dev/md0;lvm;/dev/vgxen/lv-vm01'/>
```

26 Virtualization: configuration options and settings

The documentation in this section, describes advanced management tasks and configuration options that may help technology innovators implement leading-edge virtualization solutions. It is provided as a courtesy and does not imply that all documented options and tasks are supported by Novell, Inc.

26.1 Virtual CD readers

Virtual CD readers can be set up when a virtual machine is created or added to an existing virtual machine. A virtual CD reader can be based on a physical CD/DVD, or based on an ISO image. Virtual CD readers work differently depending on whether they are paravirtual or fully virtual.

26.1.1 Virtual CD readers on paravirtual machines

A paravirtual machine can have up to 100 block devices composed of virtual CD readers and virtual disks. On paravirtual machines, virtual CD readers present the CD as a virtual disk with read-only access. Virtual CD readers cannot be used to write data to a CD.

After you have finished accessing a CD on a paravirtual machine, it is recommended that you remove the virtual CD reader from the virtual machine.

Paravirtualized guests can use the device type `devtype=cdrom`. This partly emulates the behavior of a real CD reader, and allows CDs to be changed. It is even possible to use the eject command to open the tray of the CD reader.

26.1.2 Virtual CD readers on fully virtual machines

A fully virtual machine can have up to four block devices composed of virtual CD readers and virtual disks. A virtual CD reader on a fully virtual machine interacts with an inserted CD in the way you would expect a physical CD reader to interact.

When a CD is inserted in the physical CD reader on the host computer, all virtual machines with virtual CD readers based on the physical CD reader, such as `/dev/cdrom/`, can read the inserted CD. Assuming the operating system has automount functionality, the CD should automatically appear in the file system. Virtual CD readers cannot be used to write data to a CD. They are configured as read-only devices.

26.1.3 Adding virtual CD readers

Virtual CD readers can be based on a CD inserted into the CD reader or on an ISO image file.

1. Make sure that the virtual machine is running and the operating system has finished booting.
2. Insert the desired CD into the physical CD reader or copy the desired ISO image to a location available to Dom0.
3. Select a new, unused block device in your VM Guest, such as `/dev/xvdb`.
4. Choose the CD reader or ISO image that you want to assign to the guest.
5. When using a real CD reader, use the following command to assign the CD reader to your VM Guest. In this example, the name of the guest is alice:

   ```
   > sudo xl block-attach alice target=/dev/sr0,vdev=xvdb,access=ro
   ```

6. When assigning an image file, use the following command:

   ```
   > sudo xl block-attach alice target=/path/to/file.iso,vdev=xvdb,access=ro
   ```

7. A new block device, such as `/dev/xvdb`, is added to the virtual machine.
8. If the virtual machine is running Linux, complete the following:

   a. Open a terminal in the virtual machine and enter **`fdisk -l`** to verify that the device was properly added. You can also enter **`ls /sys/block`** to see all disks available to the virtual machine.
   The CD is recognized by the virtual machine as a virtual disk with a drive designation, for example:

   ```
   /dev/xvdb
   ```

   b. Enter the command to mount the CD or ISO image using its drive designation. For example,

   ```
   > sudo mount -o ro /dev/xvdb /mnt
   ```

   mounts the CD to a mount point named **`/mnt`**.
   The CD or ISO image file should be available to the virtual machine at the specified mount point.

9. If the virtual machine is running Windows, reboot the virtual machine.
   Verify that the virtual CD reader appears in its `My Computer` section.

26.1.4 Removing virtual CD readers

1. Make sure that the virtual machine is running and the operating system has finished booting.
2. If the virtual CD reader is mounted, unmount it from within the virtual machine.
3. Enter **`xl block-list alice`** on the host view of the guest block devices.
4. Enter **`xl block-detach alice`** *`BLOCK_DEV_ID`* to remove the virtual device from the guest. If that fails, try to add `-f` to force the removal.
5. Press the hardware eject button to eject the CD.

26.2 Remote access methods

Some configurations, such as those that include rack-mounted servers, require a computer to run without a video monitor, keyboard or mouse. This type of configuration is often called `headless` and requires the use of remote administration technologies.

Typical configuration scenarios and technologies include:

Graphical desktop with X Window System server

If a graphical desktop, such as GNOME, is installed on the virtual machine host, you can use a remote viewer, such as a VNC viewer. On a remote computer, log in and manage the remote guest environment by using graphical tools, such as **`tigervnc`** or **`virt-viewer`**.

Text only

You can use the **`ssh`** command from a remote computer to log in to a virtual machine host and access its text-based console. You can then use the **`xl`** command to manage virtual machines, and the **`virt-install`** command to create new virtual machines.

26.3 VNC viewer

VNC viewer is used to view the environment of the running guest system in a graphical way. You can use it from Dom0 (known as local access or on-box access), or from a remote computer.

You can use the IP address of a VM Host Server and a VNC viewer to view the display of this VM Guest. When a virtual machine is running, the VNC server on the host assigns the virtual machine a port number to be used for VNC viewer connections. The assigned port number is the lowest port number available when the virtual machine starts. The number is only available for the virtual machine while it is running. After shutting down, the port number may be assigned to other virtual machines.

For example, if ports 1 and 2 and 4 and 5 are assigned to the running virtual machines, the VNC viewer assigns the lowest available port number, 3. If port number 3 is still in use the next time the virtual machine starts, the VNC server assigns a different port number to the virtual machine.

To use the VNC viewer from a remote computer, the firewall must permit access to as many ports as VM Guest systems run from. This means from port 5900 and up. For example, to run 10 VM Guest systems, you need to open the TCP ports 5900:5910.

To access the virtual machine from the local console running a VNC viewer client, enter one of the following commands:

- **`vncviewer ::590#`**
- **`vncviewer :#`**

`#` is the VNC viewer port number assigned to the virtual machine.

When accessing the VM Guest from a machine other than Dom0, use the following syntax:

```
> vncviewer 192.168.1.20::590#
```

In this case, the IP address of Dom0 is 192.168.1.20.

26.3.1 Assigning VNC viewer port numbers to virtual machines

Although the default behavior of VNC viewer is to assign the first available port number, you should assign a specific VNC viewer port number to a specific virtual machine.

To assign a specific port number on a VM Guest, edit the xl setting of the virtual machine and change the `vnclisten` to the desired value. For example, for port number 5902, specify 2 only, as 5900 is added automatically:

```
vfb = [ 'vnc=1,vnclisten="localhost:2"' ]
```

For more information regarding editing the xl settings of a guest domain, see *Section 24.1, "XL —Xen management tool"*.

Tip

Assign higher port numbers to avoid conflict with port numbers assigned by the VNC viewer, which uses the lowest available port number.

26.3.2 Using SDL instead of a VNC viewer

If you access a virtual machine's display from the virtual machine host console (known as local or on-box access), you should use SDL instead of VNC viewer. VNC viewer is faster for viewing desktops over a network, but SDL is faster for viewing desktops from the same computer.

To set the default to use SDL instead of VNC, change the virtual machine's configuration information to the following. For instructions, see *Section 24.1, "XL—Xen management tool"*.

```
vfb = [ 'sdl=1' ]
```

Remember that, unlike a VNC viewer window, closing an SDL window terminates the virtual machine.

26.4 Virtual keyboards

When a virtual machine is started, the host creates a virtual keyboard that matches the **`keymap`** entry according to the virtual machine's settings. If there is no **`keymap`** entry specified, the virtual machine's keyboard defaults to English (US).

To view a virtual machine's current **`keymap`** entry, enter the following command on the Dom0:

```
> xl list -l VM_NAME | grep keymap
```

To configure a virtual keyboard for a guest, use the following snippet:

```
vfb = [ 'keymap="de"' ]
```

For a complete list of supported keyboard layouts, see the `Keymaps` section of the **`xl.cfg`** manual page **`man 5 xl.cfg`**.

26.5 Dedicating CPU resources

In Xen it is possible to specify how many and which CPU cores the Dom0 or VM Guest should use to retain its performance. The performance of Dom0 is important for the overall system, as the disk and network drivers are running on it. Also I/O intensive guests' workloads may consume lots of Dom0s' CPU cycles. However, the performance of VM Guests is also important, to be able to accomplish the task they were set up for.

26.5.1 Dom0

Dedicating CPU resources to Dom0 results in a better overall performance of the virtualized environment because Dom0 has free CPU time to process I/O requests from VM Guests. Failing to dedicate exclusive CPU resources to Dom0 may results in a poor performance and can cause the VM Guests to function incorrectly.

Dedicating CPU resources involves three basic steps: modifying Xen boot line, binding Dom0's VCPUs to a physical processor, and configuring CPU-related options on VM Guests:

1. First you need to append the `dom0_max_vcpus=X` to the Xen boot line. Do so by adding the following line to `/etc/default/grub`:

   ```
   GRUB_CMDLINE_XEN="dom0_max_vcpus=X"
   ```

   If `/etc/default/grub` already contains a line setting `GRUB_CMDLINE_XEN`, rather append `dom0_max_vcpus=X` to this line.
   `X` needs to be replaced by the number of VCPUs dedicated to Dom0.

2. Update the GRUB 2 configuration file by running the following command:

   ```
   > sudo grub2-mkconfig -o /boot/grub2/grub.cfg
   ```

3. Reboot for the change to take effect.

4. The next step is to bind (or “pin”) each Dom0's VCPU to a physical processor.

   ```
   > sudo xl vcpu-pin Domain-0 0 0
   xl vcpu-pin Domain-0 1 1
   ```

   The first line binds Dom0's VCPU number 0 to the physical processor number 0, while the second line binds Dom0's VCPU number 1 to the physical processor number 1.

5. Lastly, you need to make sure no VM Guest uses the physical processors dedicated to VCPUs of Dom0. Assuming you are running an 8-CPU system, you need to add

   ```
   cpus="2-8"
   ```

   to the configuration file of the relevant VM Guest.

26.5.2 VM Guests

It is often necessary to dedicate specific CPU resources to a virtual machine. By default, a virtual machine uses any available CPU core. Its performance can be improved by assigning a reasonable number of physical processors to it as other VM Guests are not allowed to use them after that. Assuming a machine with 8 CPU cores while a virtual machine needs to use 2 of them, change its configuration file as follows:

```
vcpus=2
cpus="2,3"
```

The above example dedicates `2` processors to the VM Guest, and these being the third and fourth one, (`2` and `3` counted from zero). If you need to assign more physical processors, use the `cpus="2-8"` syntax.

If you need to change the CPU assignment for a guest named “alice” in a hotplug manner, do the following on the related Dom0:

```
> sudo xl vcpu-set alice 2
> sudo xl vcpu-pin alice 0 2
> sudo xl vcpu-pin alice 1 3
```

The example dedicates 2 physical processors to the guest, and bind its VCPU 0 to physical processor 2 and VCPU 1 to physical processor 3. Now check the assignment:

```
> sudo xl vcpu-list alice
Name                              ID  VCPUs   CPU State   Time(s) CPU Affinity
alice                             4     0     2   -b-        1.9 2-3
alice                             4     1     3   -b-        2.8 2-3
```

26.6 HVM features

In Xen, certain features are only available for fully virtualized domains. They are rarely used, but still may be interesting in specific environments.

26.6.1 Specify boot device on boot

Just as with physical hardware, it is sometimes desirable to boot a VM Guest from a different device than its own boot device. For fully virtual machines, it is possible to select a boot device with the `boot` parameter in a domain xl configuration file:

```
boot = BOOT_DEVICE
```

`BOOT_DEVICE` can be one of `c` for hard disk, `d` for CD-ROM, or `n` for Network/PXE. You can specify multiple options, and they will be attempted in the given order. For example,

```
boot = dc
```

boots from CD-ROM, and falls back to the hard disk if CD-ROM is not bootable.

26.6.2 Changing CPUIDs for guests

To be able to migrate a VM Guest from one VM Host Server to a different VM Host Server, the VM Guest system may only use CPU features that are available on both VM Host Server systems. If the actual CPUs are different on both hosts, it may be necessary to hide certain features before the VM Guest is started. This maintains the possibility to migrate the VM Guest between both hosts. For fully virtualized guests, this can be achieved by configuring the `cpuid` that is available to the guest.

To gain an overview of the current CPU, have a look at `/proc/cpuinfo`. This contains all the important information that defines the current CPU.

To redefine a CPU, first have a look at the respective cpuid definitions of the CPU vendor. These are available from:

Intel

http://www.intel.com/Assets/PDF/appnote/241618.pdf ↗

```
cpuid = "host,tm=0,sse3=0"
```

The syntax is a comma-separated list of `key=value` pairs, preceded by the word `host`. A few keys take a numerical value, while all others take a single character which describes what to do with the feature bit. See **`man 5 xl.cfg`** for a complete list of cpuid keys. The respective bits may be changed by using the following values:

1

Force the corresponding bit to `1`

`0`

Force the corresponding bit to `0`

`x`

Use the values of the default policy

`k`

Use the values defined by the host

`s`

Like `k`, but preserve the value over migrations

Tip

Remember that counting bits is done from right to left, starting with bit `0`.

26.6.3 Increasing the number of PCI-IRQs

In case you need to increase the default number of PCI-IRQs available to Dom0 and/or VM Guest, you can do so by modifying the Xen kernel command line. Use the command **`extra_guest_irqs=`** *`DOMU_IRGS,DOM0_IRGS`*. The optional first number *`DOMU_IRGS`* is common for all VM Guests, while the optional second number *`DOM0_IRGS`* (preceded by a comma) is for Dom0. Changing the setting for VM Guest has no impact on Dom0 and vice versa. For example to change Dom0 without changing VM Guest, use

```
extra_guest_irqs=,512
```

26.7 Virtual CPU scheduling

The Xen hypervisor schedules virtual CPUs individually across physical CPUs. With modern CPUs supporting multiple threads on each core, virtual CPUs can run on the same core in different threads and thus influence each other. The performance of a virtual CPU running in one thread can be noticeably affected by what other virtual CPUs in other threads are doing. When these virtual CPUs belong to different guest systems, these guests can influence each other. The effect can vary, from variations in the guest CPU time accounting to worse scenarios such as *side channel attack*.

Scheduling granularity addresses this problem. You can specify it at boot time by using a Xen boot parameter:

```
sched-gran=GRANULARITY
```

Replace `GRANULARITY` with one of:

cpu

The regular scheduling of the Xen hypervisor. Virtual CPUs of different guests can share one physical CPU core. This is the default.

core

Virtual CPUs of a virtual core are always scheduled together on one physical core. Two or more virtual CPUs from different virtual cores will never be scheduled on the same physical core. Therefore, certain physical cores may have several of their CPUs left idle, even if there are virtual CPUs wanting to run. The impact on performance will depend on the actual workload being run inside of the guest systems. In most of the analyzed cases, the observed performance degradation, especially if under considerable load, was smaller than disabling HyperThreading, which leaves all the cores with just one thread (see the `smt` boot option at https://xenbits.xen.org/docs/unstable/misc/xen-command-line.html#smt-x86 ↗).

socket

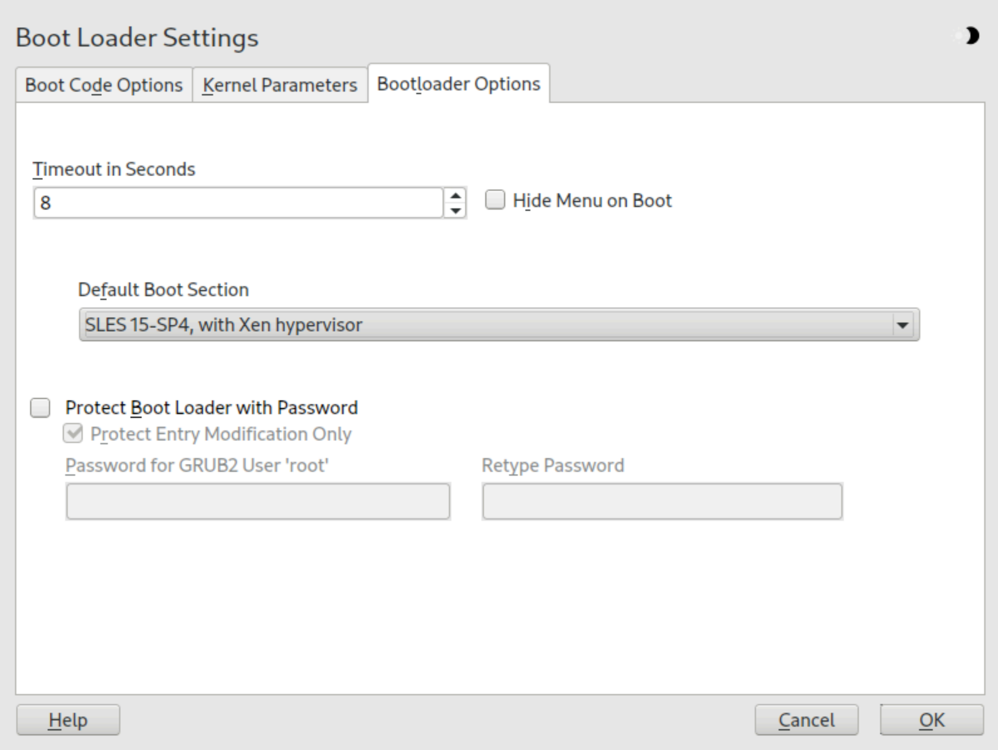
The granularity goes even higher to a CPU socket level.

27 Administrative tasks

27.1 The boot loader program

The boot loader controls how the virtualization software boots and runs. You can modify the boot loader properties by using YaST, or by directly editing the boot loader configuration file.

The YaST boot loader program is located at *YaST* › *System* › *Boot Loader*. Click the *Bootloader Options* tab and select the line containing the Xen kernel as the *Default Boot Section*.



Boot Loader Settings

Timeout in Seconds: 8

□ Hide Menu on Boot

Default Boot Section: SLES 15-SP4, with Xen hypervisor

□ Protect Boot Loader with Password

☑ Protect Entry Modification Only

Password for GRUB2 User 'root'

Retype Password

FIGURE 27.1: BOOT LOADER SETTINGS

Confirm with *OK*. Next time you boot the host, it can provide the Xen virtualization environment.

You can use the Boot Loader program to specify functionality, such as:

- Pass kernel command-line parameters.
- Specify the kernel image and initial RAM disk.
- Select a specific hypervisor.
- Pass additional parameters to the hypervisor. See http://xenbits.xen.org/docs/unstable/misc/xen-command-line.html ↗ for their complete list.

You can customize your virtualization environment by editing the `/etc/default/grub` file. Add the following line to this file: `GRUB_CMDLINE_XEN="<boot_parameters>"`. Do not forget to run **`grub2-mkconfig -o /boot/grub2/grub.cfg`** after editing the file.

27.2 Sparse image files and disk space

If the host's physical disk reaches a state where it has no available space, a virtual machine using a virtual disk based on a sparse image file cannot write to its disk. Consequently, it reports I/O errors.

If this situation occurs, you should free up available space on the physical disk, remount the virtual machine's file system, and set the file system back to read-write.

To check the actual disk requirements of a sparse image file, use the command **`du -h <image file>`**.

To increase the available space of a sparse image file, first increase the file size and then the file system.

Warning: Back up before resizing

Touching the sizes of partitions or sparse files always bears the risk of data failure. Do not work without a backup.

The resizing of the image file can be done online, while the VM Guest is running. Increase the size of a sparse image file with:

```
> sudo dd if=/dev/zero of=<image file> count=0 bs=1M seek=<new size in MB>
```

For example, to increase the file `/var/lib/xen/images/sles/disk0` to a size of 16GB, use the command:

```
> sudo dd if=/dev/zero of=/var/lib/xen/images/sles/disk0 count=0 bs=1M seek=16000
```

Note: Increasing non-sparse images

It is also possible to increase the image files of devices that are not sparse files. However, you must know exactly where the previous image ends. Use the seek parameter to point to the end of the image file and use a command similar to the following:

```
> sudo dd if=/dev/zero of=/var/lib/xen/images/sles/disk0 seek=8000 bs=1M count=2000
```

Be sure to use the right seek, else data loss may happen.

If the VM Guest is running during the resize operation, also resize the loop device that provides the image file to the VM Guest. First detect the correct loop device with the command:

```
> sudo losetup -j /var/lib/xen/images/sles/disk0
```

Then resize the loop device, for example `/dev/loop0`, with the following command:

```
> sudo losetup -c /dev/loop0
```

Finally check the size of the block device inside the guest system with the command **`fdisk -l /dev/xvdb`**. Replace the device name with your increased disk.

The resizing of the file system inside the sparse file involves tools that are depending on the actual file system.

27.3 Migrating Xen VM Guest systems

With Xen it is possible to migrate a VM Guest system from one VM Host Server to another with almost no service interruption. This could be used, for example, to move a busy VM Guest to a VM Host Server that has stronger hardware or is not yet loaded. Or, if a service of a VM Host Server is required, all VM Guest systems running on this machine can be migrated to other machines to avoid interruption of service. These are only two examples—many more reasons may apply to your personal situation.

Before starting, certain preliminary considerations regarding the VM Host Server should be taken into account:

- All VM Host Server systems should use a similar CPU. The frequency is not so important, but they should be using the same CPU family. To get more information about the used CPU, use `cat /proc/cpuinfo`. Find more details about comparing host CPU features in *Section 27.3.1, "Detecting CPU features"*.
- All resources that are used by a specific guest system must be available on all involved VM Host Server systems—for example all used block devices must exist on both VM Host Server systems.
- If the hosts included in the migration process run in different subnets, make sure that either DHCP relay is available to the guests, or for guests with static network configuration, set up the network manually.
- Using special features like `PCI Pass-Through` may be problematic. Do not implement these when deploying for an environment that should migrate VM Guest systems between different VM Host Server systems.
- For fast migrations, a fast network is mandatory. If possible, use GB Ethernet and fast switches. Deploying VLAN may also help avoid collisions.

27.3.1 Detecting CPU features

By using the `cpuid` and `xen_maskcalc.py` tools, you can compare features of a CPU on the host from where you are migrating the source VM Guest with the features of CPUs on the target hosts. This way you can better predict if the guest migrations will be successful.

1. Run the `cpuid -1r` command on each Dom0 that is supposed to run or receive the migrated VM Guest and capture the output in text files, for example:

```
tux@vm_host1 > sudo cpuid -1r > vm_host1.txt
tux@vm_host2 > sudo cpuid -1r > vm_host2.txt
tux@vm_host3 > sudo cpuid -1r > vm_host3.txt
```

2. Copy all the output text files on a host with the `xen_maskcalc.py` script installed.
3. Run the `xen_maskcalc.py` script on all output text files:

```
> sudo xen_maskcalc.py vm_host1.txt vm_host2.txt vm_host3.txt
```

```
cpuid = [
    "0x00000001:ecx=x00xxxxxx0xxxxxxxxx00xxxxxxxxxxx",
    "0x00000007,0x00:ebx=xxxxxxxxxxxxxxxxxx00x0000x0x0x00"
]
```

4. Copy the output `cpuid=[...]` configuration snipped into the **`xl`** configuration of the migrated guest `domU.cfg` or alternatively to its `libvirt`'s XML configuration.

5. Start the source guest with the *trimmed* CPU configuration. The guest can now only use CPU features which are present on each of the hosts.

27.3.1.1 More information

You can find more details about `cpuid` at http://etallen.com/cpuid.html.

You can download the latest version of the CPU mask calculator from https://github.com/twizted/xen_maskcalc.

27.3.2 Preparing block devices for migrations

The block devices needed by the VM Guest system must be available on all involved VM Host Server systems. This is done by implementing a specific kind of shared storage that serves as a container for the root file system of the migrated VM Guest system. Common possibilities include:

- `iSCSI` can be set up to give access to the same block devices from different systems at the same time.
- `NFS` is a widely used root file system that can easily be accessed from different locations. For more information, see *Book* “Reference”, *Chapter 22 “Sharing file systems with NFS”*.
- `DRBD` can be used if only two VM Host Server systems are involved. This adds certain extra data security, because the used data is mirrored over the network. .
- `SCSI` can also be used if the available hardware permits shared access to the same disks.
- `NPIV` is a special mode to use Fibre channel disks. However, in this case, all migration hosts must be attached to the same Fibre channel switch. For more information about NPIV, see *Section 25.1, “Mapping physical storage to virtual disks”*. Commonly, this works if the Fibre channel environment supports 4 Gbps or faster connections.

27.3.3 Migrating VM Guest systems

The actual migration of the VM Guest system is done with the command:

```
> sudo xl migrate <domain_name> <host>
```

The speed of the migration depends on how fast the memory print can be saved to disk, sent to the new VM Host Server and loaded there. This means that small VM Guest systems can be migrated faster than big systems with a lot of memory.

27.4 Monitoring Xen

For a regular operation of many virtual guests, having a possibility to check the sanity of all the different VM Guest systems is indispensable. Xen offers several tools besides the system tools to gather information about the system.

Tip: Monitoring the VM Host Server

Basic monitoring of the VM Host Server (I/O and CPU) is available via the Virtual Machine Manager. Refer to *Section 10.8.1, “Monitoring with Virtual Machine Manager”* for details.

27.4.1 Monitor Xen with `xentop`

The preferred terminal application to gather information about Xen virtual environment is `xentop`. Be aware that this tool needs a rather broad terminal, else it inserts line breaks into the display.

`xentop` has several command keys that can give you more information about the system that is monitored. For example:

D

Change the delay between the refreshes of the screen.

N

Also display network statistics. Note, that only standard configurations are displayed. If you use a special configuration like a routed network, no network is displayed.

B

Display the respective block devices and their cumulated usage count.

For more information about `xentop`, see the manual page `man 1 xentop`.

Tip: `virt-top`

libvirt offers the hypervisor-agnostic tool `virt-top`, which is recommended for monitoring VM Guests. See *Section 10.8.2, “Monitoring with `virt-top`”* for details.

27.4.2 Additional tools

There are many system tools that also help monitoring or debugging a running openSUSE system. Many of these are covered in *Book “System Analysis and Tuning Guide”, Chapter 2 “System monitoring utilities”*. Especially useful for monitoring a virtualization environment are the following tools:

ip

The command-line utility `ip` may be used to monitor arbitrary network interfaces. This is especially useful if you have set up a network that is routed or applied a masqueraded network. To monitor a network interface with the name `alice.0`, run the following command:

```
> watch ip -s link show alice.0
```

bridge

In a standard setup, all the Xen VM Guest systems are attached to a virtual network bridge. `bridge` allows you to determine the connection between the bridge and the virtual network adapter in the VM Guest system. For example, the output of `bridge link` may look like the following:

```
2: eth0 state DOWN : <NO-CARRIER, ...,UP> mtu 1500 master br0
8: vnet0 state UNKNOWN : <BROADCAST, ...,LOWER_UP> mtu 1500 master virbr0 \
  state forwarding priority 32 cost 100
```

This shows that there are two virtual bridges defined on the system. One is connected to the physical Ethernet device `eth0`, the other one is connected to a VLAN interface `vnet0`.

iptables-save

Especially when using masquerade networks, or if several Ethernet interfaces are set up together with a firewall setup, it may be helpful to check the current firewall rules.

The command `iptables` may be used to check all the different firewall settings. To list all the rules of a chain, or even of the complete setup, you may use the commands `iptables-save` or `iptables -S`.

27.5 Providing host information for VM Guest systems

In a standard Xen environment, the VM Guest systems have only limited information about the VM Host Server system they are running on. If a guest should know more about the VM Host Server it runs on, `vhostmd` can provide more information to selected guests. To set up your system to run `vhostmd`, proceed as follows:

1. Install the package vhostmd on the VM Host Server.
2. To add or remove `metric` sections from the configuration, edit the file `/etc/vhostmd/vhostmd.conf`. However, the default works well.
3. Check the validity of the `vhostmd.conf` configuration file with the command:

   ```
   > cd /etc/vhostmd
   > xmllint --postvalid --noout vhostmd.conf
   ```

4. Start the vhostmd daemon with the command **`sudo systemctl start vhostmd`**.
   If vhostmd should be started automatically during start-up of the system, run the command:

   ```
   > sudo systemctl enable vhostmd
   ```

5. Attach the image file `/dev/shm/vhostmd0` to the VM Guest system named alice with the command:

   ```
   > xl block-attach opensuse /dev/shm/vhostmd0,,xvdb,ro
   ```

6. Log on the VM Guest system.
7. Install the client package `vm-dump-metrics`.
8. Run the command **`vm-dump-metrics`**. To save the result to a file, use the option `-d <filename>`.

The result of the `vm-dump-metrics` is an XML output. The respective metric entries follow the DTD `/etc/vhostmd/metric.dtd`.

For more information, see the manual pages **`man 8 vhostmd`** and `/usr/share/doc/vhostmd/README` on the VM Host Server system. On the guest, see the manual page **`man 1 vm-dump-metrics`**.

28 XenStore: configuration database shared between domains

This section introduces basic information about XenStore, its role in the Xen environment, the directory structure of files used by XenStore, and the description of XenStore's commands.

28.1 Introduction

XenStore is a database of configuration and status information shared between VM Guests and the management tools running in Dom0. VM Guests and the management tools read and write to XenStore to convey configuration information, status updates, and state changes. The XenStore database is managed by Dom0 and supports simple operations, such as reading and writing a key. VM Guests and management tools can be notified of any changes in XenStore by watching entries of interest. The `xenstored` daemon is managed by the `xencommons` service.

XenStore is located on Dom0 in a single database file `/var/lib/xenstored/tdb` (`tdb` represents *tree database*).

28.2 File system interface

XenStore database content is represented by a virtual file system similar to `/proc` (for more information on `/proc`, see *Book "System Analysis and Tuning Guide", Chapter 2 "System monitoring utilities", Section 2.6 "The* `/proc` *file system"*). The tree has three main paths: `/vm`, `/local/domain`, and `/tool`.

- `/vm` - stores information about the VM Guest configuration.
- `/local/domain` - stores information about VM Guest on the local node.
- `/tool` - stores general information about multiple tools.

Tip

Each VM Guest has two different ID numbers. The *universal unique identifier* (UUID) remains the same even if the VM Guest is migrated to another machine. The *domain identifier* (DOMID) is an identification number that represents a particular running instance. It typically changes when the VM Guest is migrated to another machine.

28.2.1 XenStore commands

The file system structure of the XenStore database can be operated with the following commands:

xenstore-ls

Displays the full dump of the XenStore database.

xenstore-read path_to_xenstore_entry

Displays the value of the specified XenStore entry.

xenstore-exists xenstore_path

Reports whether the specified XenStore path exists.

xenstore-list xenstore_path

Displays all the children entries of the specified XenStore path.

xenstore-write path_to_xenstore_entry

Updates the value of the specified XenStore entry.

xenstore-rm xenstore_path

Removes the specified XenStore entry or directory.

xenstore-chmod xenstore_path mode

Updates the read/write permission on the specified XenStore path.

xenstore-control

Sends a command to the xenstored back-end, such as triggering an integrity check.

28.2.2 /vm

The /vm path is indexed by the UUID of each VM Guest, and stores configuration information such as the number of virtual CPUs and the amount of allocated memory. There is a /vm/<uuid> directory for each VM Guest. To list the directory content, use **xenstore-list**.

```
> sudo xenstore-list /vm
00000000-0000-0000-0000-000000000000
9b30841b-43bc-2af9-2ed3-5a649f466d79-1
```

The first line of the output belongs to Dom0, and the second one to a running VM Guest. The following command lists all the entries related to the VM Guest:

```
> sudo xenstore-list /vm/9b30841b-43bc-2af9-2ed3-5a649f466d79-1
```

```
image
rtc
device
pool_name
shadow_memory
uuid
on_reboot
start_time
on_poweroff
bootloader_args
on_crash
vcpus
vcpu_avail
bootloader
name
```

To read a value of an entry, for example, the number of virtual CPUs dedicated to the VM Guest, use **`xenstore-read`**:

```
> sudo xenstore-read /vm/9b30841b-43bc-2af9-2ed3-5a649f466d79-1/vcpus
1
```

A list of selected `/vm/<uuid>` entries follows:

`uuid`
: UUID of the VM Guest. It does not change during the migration process.

`on_reboot`
: Specifies whether to destroy or restart the VM Guest in response to a reboot request.

`on_poweroff`
: Specifies whether to destroy or restart the VM Guest in response to a halt request.

`on_crash`
: Specifies whether to destroy or restart the VM Guest in response to a crash.

`vcpus`
: Number of virtual CPUs allocated to the VM Guest.

`vcpu_avail`
: Bitmask of active virtual CPUs for the VM Guest. The bitmask has several bits equal to the value of `vcpus`, with a bit set for each online virtual CPU.

`name`
: The name of the VM Guest.

Regular VM Guests (not Dom0) use the `/vm/<uuid>/image` path:

```
> sudo xenstore-list /vm/9b30841b-43bc-2af9-2ed3-5a649f466d79-1/image
ostype
kernel
cmdline
ramdisk
dmargs
device-model
display
```

An explanation of the used entries follows:

`ostype`

The OS type of the VM Guest.

`kernel`

The path on Dom0 to the kernel for the VM Guest.

`cmdline`

The kernel command line for the VM Guest used when booting.

`ramdisk`

The path on Dom0 to the RAM disk for the VM Guest.

`dmargs`

Shows arguments passed to the QEMU process. If you look at the QEMU process with **`ps`**, you should see the same arguments as in `/vm/<uuid>/image/dmargs`.

28.2.3 /local/domain/<domid>

This path is indexed by the running domain (VM Guest) ID, and contains information about the running VM Guest. Remember that the domain ID changes during VM Guest migration. The following entries are available:

`vm`

The path of the `/vm` directory for this VM Guest.

`on_reboot, on_poweroff, on_crash, name`

See identical options in *Section 28.2.2, “/vm”*

`domid`

Domain identifier for the VM Guest.

`cpu`

The current CPU to which the VM Guest is pinned.

`cpu_weight`

The weight assigned to the VM Guest for scheduling purposes. Higher weights use the physical CPUs more often.

Apart from the individual entries described above, there are also several subdirectories under `/local/domain/<domid>`, containing specific entries. To see all entries available, refer to XenStore Reference (http://wiki.xen.org/wiki/XenStore_Reference) ↗.

`/local/domain/<domid>/memory`

Contains memory information. `/local/domain/<domid>/memory/target` contains target memory size for the VM Guest (in kilobytes).

`/local/domain/<domid>/console`

Contains information about a console used by the VM Guest.

`/local/domain/<domid>/backend`

Contains information about all back-end devices used by the VM Guest. The path has subdirectories of its own.

`/local/domain/<domid>/device`

Contains information about the front-end devices for the VM Guest.

`/local/domain/<domid>/device-misc`

Contains miscellaneous information about devices.

`/local/domain/<domid>/store`

Contains information about the VM Guest's store.

29 Xen as a high-availability virtualization host

Setting up two Xen hosts as a failover system has several advantages compared to a setup where every server runs on dedicated hardware.

- Failure of a single server does not cause major interruption of the service.
- A single big machine is normally way cheaper than multiple smaller machines.
- Adding new servers as needed is a trivial task.
- The usage of the server is improved, which has positive effects on the power consumption of the system.

The setup of migration for Xen hosts is described in *Section 27.3, "Migrating Xen VM Guest systems"*. In the following, several typical scenarios are described.

29.1 Xen HA with remote storage

Xen can directly provide several remote block devices to the respective Xen guest systems. These include iSCSI, NPIV and NBD. They may be used to do live migrations. When a storage system is already in place, first try to use the same device type you already used in the network.

If the storage system cannot be used directly but provides a possibility to offer the needed space over NFS, it is also possible to create image files on NFS. If NFS is available on all Xen host systems, this method also allows live migrations of Xen guests.

When setting up a new system, one of the main considerations is whether a dedicated storage area network should be implemented. The following possibilities are available:

TABLE 29.1: XEN REMOTE STORAGE

Method	Complexity	Comments
Ethernet	low	All block device traffic goes over the same Ethernet interface as the network traffic. This may be limiting the performance of the guest.

Method	Complexity	Comments
Ethernet dedicated to storage.	medium	Running the storage traffic over a dedicated Ethernet interface may eliminate a bottleneck on the server side. However, planning your own network with your own IP address range and a VLAN dedicated to storage requires certain considerations.
NPIV	high	NPIV is a method to virtualize Fibre channel connections. This is available with adapters that support a data rate of at least 4 Gbit/s and allows the setup of complex storage systems.

Typically, a 1 Gbit/s Ethernet device can fully use a typical hard disk or storage system. When using fast storage systems, such an Ethernet device may limit the speed of the system.

29.2 Xen HA with local storage

For space or budget reasons, it may be necessary to rely on storage that is local to the Xen host systems. To still maintain the possibility of live migrations, it is necessary to build block devices that are mirrored to both Xen hosts. The software that allows this is called Distributed Replicated Block Device (DRBD).

If a system that uses DRBD to mirror the block devices or files between two Xen hosts should be set up, both hosts should use the identical hardware. If one of the hosts has slower hard disks, both hosts suffer from this limitation.

During the setup, each of the required block devices should use its own DRBD device. The setup of such a system is a complex task.

29.3 Xen HA and private bridges

When using several guest systems that need to communicate between each other, it is possible to do this over the regular interface. However, for security reasons it may be advisable to create a bridge that is only connected to guest systems.

In an HA environment that also should support live migrations, such a private bridge must be connected to the other Xen hosts. This is possible by using dedicated physical Ethernet devices and a dedicated network.

A different implementation method is using VLAN interfaces. In that case, all the traffic goes over the regular Ethernet interface. However, the VLAN interface does not get the regular traffic, because only the VLAN packets that are tagged for the correct VLAN are forwarded.

For more information about the setup of a VLAN interface see *Section 8.1.1.4, "Using VLAN interfaces"*.

30 Xen: converting a paravirtual (PV) guest into a fully virtual (FV/HVM) guest

This chapter explains how to convert a Xen paravirtual machine into a Xen fully virtualized machine.

PROCEDURE 30.1: GUEST SIDE

To start the guest in FV mode, you need to run the following steps inside the guest.

1. Before converting the guest, apply all pending patches and reboot the guest.
2. FV machines use the `-default` kernel. If this kernel is not already installed, install the `kernel-default` package (while running in PV mode).
3. PV machines typically use disk names such as `vda*`. These names must be changed to the FV `hd*` syntax. This change must be done in the following files:
   - `/etc/fstab`
   - `/boot/grub/menu.lst` (SLES 11 only)
   - `/boot/grub*/device.map`
   - `/etc/sysconfig/bootloader`
   - `/etc/default/grub` (SLES 12, 15, openSUSE)

   ### Note: Prefer UUIDs

   You should use UUIDs or logical volumes within your `/etc/fstab`. Using UUIDs simplifies the use of attached network storage, multipathing and virtualization. To find the UUID of your disk, use the command **`blkid`**.

4. To avoid any error regenerating the `initrd` with the required modules, you can create a symbolic link from `/dev/hda2` to `/dev/xvda2` etc. by using the **`ln`**:

```
ln -sf /dev/xvda2 /dev/hda2
ln -sf /dev/xvda1 /dev/hda1
.....
```

5. PV and FV machines use different disk and network driver modules. These FV modules must be added to the initrd manually. The expected modules are `xen-vbd` (for disk) and `xen-vnif` (for network). These are the only PV drivers for a fully virtualized VM Guest. All other modules, such as `ata_piix`, `ata_generic` and `libata`, should be added automatically.

   ### Tip: Adding modules to the initrd

   - On SLES 11, you can add modules to the `INITRD_MODULES` line in the `/etc/sysconfig/kernel` file. For example:

     ```
     INITRD_MODULES="xen-vbd xen-vnif"
     ```

     Run **`dracut`** to build a new initrd containing the modules.

   - On SLES 12, 15, and openSUSE open or create `/etc/dracut.conf.d/10-virt.conf` and add the modules with `force_drivers` by adding a line as in the example below (mind the leading whitespace):

     ```
     force_drivers+=" xen-vbd xen-vnif"
     ```

     Run **`dracut -f --kver`** *`KERNEL_VERSION`***`-default`** to build a new initrd (for the default version of the kernel) that contains the required modules.

     Find your kernel version. Use the **`uname -r`** command to get the current version used on your system.

6. Before shutting down the guest, set the default boot parameter to the `-default` kernel using **`yast bootloader`**.

7. Under openSUSE Leap 11, if you have an X server running on your guest, you need to adjust the `/etc/X11/xorg.conf` file to adjust the X driver. Search for `fbdev` and change to `cirrus`.

   ```
   Section "Device"
             Driver       "cirrus"
             ......
             EndSection
   ```

Note: openSUSE Leap 12/15 and Xorg

Under openSUSE Leap 12/15, Xorg automatically adjusts the driver needed to be able to get a working X server.

8. Shut down the guest.

PROCEDURE 30.2: HOST SIDE

The following steps explain the action that you need to perform on the host.

1. To start the guest in FV mode, the configuration of the VM must be modified to match an FV configuration. Editing the configuration of the VM can easily be done using **`virsh edit [DOMAIN]`**. The following changes are recommended:

   - Make sure the machine, the type, and the `loader` entries in the OS section are changed from `xenpv` to `xenfv`. The updated OS section should look similar to:

     ```
     <os>
               <type arch='x86_64' machine='xenfv'>hvm</type>
               <loader>/usr/lib/xen/boot/hvmloader</loader>
               <boot dev='hd'/>
     </os>
     ```

   - In the OS section, remove anything that is specific to PV guests:

     - `<bootloader>pygrub</bootloader>`
     - `<kernel>/usr/lib/grub2/x86_64-xen/grub.xen</kernel>`
     - `<cmdline>xen-fbfront.video=4,1024,768</cmdline>`

   - In the devices section, add the qemu emulator as:

     ```
     <emulator>/usr/lib/xen/bin/qemu-system-i386</emulator>
     ```

   - Update the disk configuration so the target device and bus use the FV syntax. This requires replacing the `xen` disk bus with `ide`, and the `vda` target device with `hda`. The changes should look similar to:

     ```
     <target dev='hda' bus='ide'/>
     ```

- Change the bus for the mouse and keyboard from `xen` to `ps2`. Also add a new USB tablet device:

```
<input type='mouse' bus='ps2'/>
          <input type='keyboard' bus='ps2'/>
<input type='tablet' bus='usb'/>
```

- Change the console target type from `xen` to `serial`:

```
<console type='pty'>
          <target type='serial' port='0'/>
</console>
```

- Change the video configuration from `xen` to `cirrus`, with 8 MB of VRAM:

```
<video>
          <model type='cirrus' vram='8192' heads='1' primary='yes'/>
</video>
```

- If desired, add `acpi` and `apic` to the features of the VM:

```
<features>
          <acpi/>
          <apic/>
</features>
```

2. Start the guest (using **`virsh`** or **`virt-manager`**). If the guest is running kernel-default (as verified through **`uname -a`**), the machine is running in Fully Virtual mode.

Note: guestfs-tools

To script this process, or work on disk images directly, you can use the guestfs-tools suite (see *Section 18.3, “Guestfs tools”* for more information). Several tools exist to help modify disk images.

V Managing virtual machines with QEMU

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31 QEMU overview

QEMU is a fast, cross-platform open source machine emulator which can emulate many hardware architectures. QEMU lets you run a complete unmodified operating system (VM Guest) on top of your existing system (VM Host Server). You can also use QEMU for debugging purposes—you can easily stop your running virtual machine, inspect its state, and save and restore it later.

QEMU mainly consists of the following parts:

- Processor emulator.
- Emulated devices, such as graphic card, network card, hard disks, or mouse.
- Generic devices used to connect the emulated devices to the related host devices.
- Debugger.
- User interface used to interact with the emulator.

QEMU is central to KVM and Xen Virtualization, where it provides the general machine emulation. Xen's usage of QEMU is partially hidden from the user, while KVM's usage exposes most QEMU features transparently. If the VM Guest hardware architecture is the same as the VM Host Server's architecture, QEMU can use the KVM acceleration (SUSE only supports QEMU with the KVM acceleration loaded).

Apart from providing a core virtualization infrastructure and processor-specific drivers, QEMU also provides an architecture-specific user space program for managing VM Guests. Depending on the architecture this program is one of:

- **`qemu-system-i386`**
- **`qemu-system-s390x`**
- **`qemu-system-x86_64`**
- **`qemu-system-aarch64`**

In the following this command is called **`qemu-system-`***`ARCH`*; in examples the **`qemu-system-x86_64`** command is used.

32 Setting up a KVM VM Host Server

This section documents how to set up and use openSUSE Leap 15.5 as a QEMU-KVM based virtual machine host.

Tip: Resources

The virtual guest system needs the same hardware resources as if it were installed on a physical machine. The more guests you plan to run on the host system, the more hardware resources—CPU, disk, memory and network—you need to add to the VM Host Server.

32.1 CPU support for virtualization

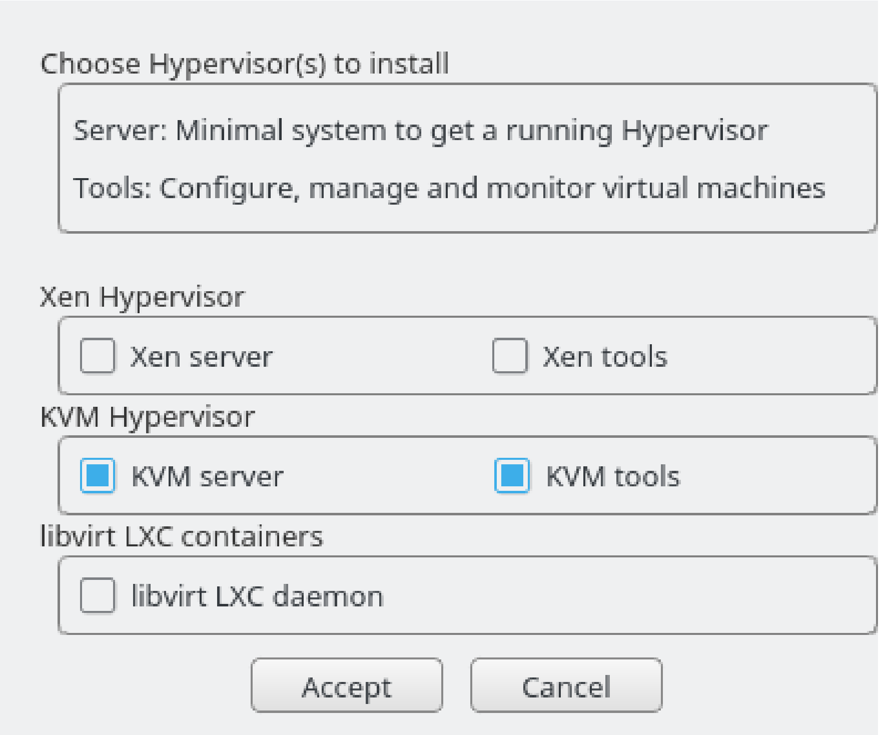
To run KVM, your CPU must support virtualization, and virtualization needs to be enabled in BIOS. The file `/proc/cpuinfo` includes information about your CPU features.

32.2 Required software

The KVM host requires several packages to be installed. To install all necessary packages, do the following:

1. Verify that the `yast2-vm` package is installed. This package is YaST's configuration tool that simplifies the installation of virtualization hypervisors.

2. Run *YaST* › *Virtualization* › *Install Hypervisor and Tools*.



Choose Hypervisor(s) to install

Server: Minimal system to get a running Hypervisor

Tools: Configure, manage and monitor virtual machines

Xen Hypervisor

□ Xen server □ Xen tools

KVM Hypervisor

☑ KVM server ☑ KVM tools

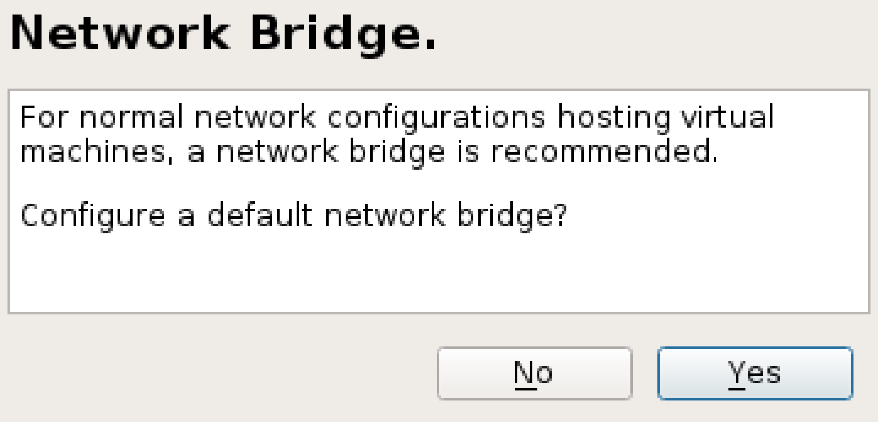
libvirt LXC containers

□ libvirt LXC daemon

FIGURE 32.1: INSTALLING THE KVM HYPERVISOR AND TOOLS

3. Select *KVM server* and preferably also *KVM tools*, and confirm with *Accept*.

4. During the installation process, you can optionally let YaST create a *Network Bridge* for you automatically. If you do not plan to dedicate an additional physical network card to your virtual guests, network bridge is a standard way to connect the guest machines to the network.



Network Bridge.

For normal network configurations hosting virtual machines, a network bridge is recommended.

Configure a default network bridge?

FIGURE 32.2: NETWORK BRIDGE

5. After all the required packages are installed (and new network setup activated), try to load the KVM kernel module relevant for your CPU type— `kvm_intel` or `kvm_amd`:

   ```
   # modprobe kvm_intel
   ```

   Check if the module is loaded into memory:

   ```
   > lsmod | grep kvm
   kvm_intel             64835  6
   kvm                  411041  1 kvm_intel
   ```

   Now the KVM host is ready to serve KVM VM Guests. For more information, see *Chapter 34, Running virtual machines with qemu-system-ARCH*.

32.3 KVM host-specific features

You can improve the performance of KVM-based VM Guests by letting them fully use specific features of the VM Host Server's hardware (*paravirtualization*). This section introduces techniques to make the guests access the physical host's hardware directly—without the emulation layer—to make the most use of it.

Tip

Examples included in this section assume basic knowledge of the **`qemu-system-`***`ARCH`* command line options. For more information, see *Chapter 34, Running virtual machines with qemu-system-ARCH*.

32.3.1 Using the host storage with `virtio-scsi`

`virtio-scsi` is an advanced storage stack for KVM. It replaces the former `virtio-blk` stack for SCSI devices pass-through. It has several advantages over `virtio-blk`:

Improved scalability

KVM guests have a limited number of PCI controllers, which results in a limited number of attached devices. `virtio-scsi` solves this limitation by grouping multiple storage devices on a single controller. Each device on a `virtio-scsi` controller is represented as a logical unit, or *LUN*.

Standard command set

`virtio-blk` uses a small set of commands that need to be known to both the `virtio-blk` driver and the virtual machine monitor, and so introducing a new command requires updating both the driver and the monitor.

By comparison, `virtio-scsi` does not define commands, but rather a transport protocol for these commands following the industry-standard SCSI specification. This approach is shared with other technologies, such as Fibre Channel, ATAPI and USB devices.

Device naming

`virtio-blk` devices are presented inside the guest as `/dev/vdX`, which is different from device names in physical systems and may cause migration problems.

`virtio-scsi` keeps the device names identical to those on physical systems, making the virtual machines easily relocatable.

SCSI device pass-through

For virtual disks backed by a whole LUN on the host, it is preferable for the guest to send SCSI commands directly to the LUN (pass-through). This is limited in `virtio-blk`, as guests need to use the virtio-blk protocol instead of SCSI command pass-through, and, moreover, it is not available for Windows guests. `virtio-scsi` natively removes these limitations.

32.3.1.1 `virtio-scsi` usage

KVM supports the SCSI pass-through feature with the `virtio-scsi-pci` device:

```
# qemu-system-x86_64 [...] \
-device virtio-scsi-pci,id=scsi
```

32.3.2 Accelerated networking with `vhost-net`

The `vhost-net` module is used to accelerate KVM's paravirtualized network drivers. It provides better latency and greater network throughput. Use the `vhost-net` driver by starting the guest with the following example command line:

```
# qemu-system-x86_64 [...] \
-netdev tap,id=guest0,vhost=on,script=no \
-net nic,model=virtio,netdev=guest0,macaddr=00:16:35:AF:94:4B
```

`guest0` is an identification string of the vhost-driven device.

32.3.3 Scaling network performance with multiqueue virtio-net

As the number of virtual CPUs increases in VM Guests, QEMU offers a way of improving the network performance using *multiqueue*. Multiqueue virtio-net scales the network performance by allowing VM Guest virtual CPUs to transfer packets in parallel. Multiqueue support is required on both the VM Host Server and VM Guest sides.

Tip: Performance benefit

The multiqueue virtio-net solution is most beneficial in the following cases:

- Network traffic packets are large.
- VM Guest has many connections active at the same time, mainly between the guest systems, or between the guest and the host, or between the guest and an external system.
- The number of active queues is equal to the number of virtual CPUs in the VM Guest.

Note

While multiqueue virtio-net increases the total network throughput, it increases CPU consumption as it uses of the virtual CPU's power.

PROCEDURE 32.1: HOW TO ENABLE MULTIQUEUE VIRTIO-NET

The following procedure lists important steps to enable the multiqueue feature with **`qemu-system-ARCH`**. It assumes that a tap network device with multiqueue capability (supported since kernel version 3.8) is set up on the VM Host Server.

1. In **`qemu-system-ARCH`**, enable multiqueue for the tap device:

   ```
   -netdev tap,vhost=on,queues=2*N
   ```

   where `N` stands for the number of queue pairs.

2. In **`qemu-system-ARCH`**, enable multiqueue and specify MSI-X (Message Signaled Interrupt) vectors for the virtio-net-pci device:

   ```
   -device virtio-net-pci,mq=on,vectors=2*N+2
   ```

where the formula for the number of MSI-X vectors results from: N vectors for TX (transmit) queues, N for RX (receive) queues, one for configuration purposes, and one for possible VQ (vector quantization) control.

3. In VM Guest, enable multiqueue on the relevant network interface (`eth0` in this example):

   ```
   > sudo ethtool -L eth0 combined 2*N
   ```

The resulting **`qemu-system-ARCH`** command line looks similar to the following example:

```
qemu-system-x86_64 [...] -netdev tap,id=guest0,queues=8,vhost=on \
-device virtio-net-pci,netdev=guest0,mq=on,vectors=10
```

Note that the `id` of the network device (`guest0`) needs to be identical for both options.

Inside the running VM Guest, specify the following command with `root` privileges:

```
> sudo ethtool -L eth0 combined 8
```

Now the guest system networking uses the multiqueue support from the **`qemu-system-ARCH`** hypervisor.

32.3.4 VFIO: secure direct access to devices

Directly assigning a PCI device to a VM Guest (PCI pass-through) avoids performance issues caused by avoiding any emulation in performance-critical paths. VFIO replaces the traditional KVM PCI Pass-Through device assignment. A prerequisite for this feature is a VM Host Server configuration as described in *Important: Requirements for VFIO and SR-IOV*.

To be able to assign a PCI device via VFIO to a VM Guest, you need to find out which IOMMU Group it belongs to. The *IOMMU* (input/output memory management unit that connects a direct memory access-capable I/O bus to the main memory) API supports the notion of groups. A group is a set of devices that can be isolated from all other devices in the system. Groups are therefore the unit of ownership used by *VFIO*.

PROCEDURE 32.2: ASSIGNING A PCI DEVICE TO A VM GUEST VIA VFIO

1. Identify the host PCI device to assign to the guest.

   ```
   > sudo lspci -nn
   [...]
   00:10.0 Ethernet controller [0200]: Intel Corporation 82576 \
   Virtual Function [8086:10ca] (rev 01)
   ```

```
[...]
```

Note down the device ID (`00:10.0` in this case) and the vendor ID (`8086:10ca`).

2. Find the IOMMU group of this device:

   ```
   > sudo readlink /sys/bus/pci/devices/0000\:00\:10.0/iommu_group
   ../../../kernel/iommu_groups/20
   ```

   The IOMMU group for this device is `20`. Now you can check the devices belonging to the same IOMMU group:

   ```
   > sudo ls -l /sys/bus/pci/devices/0000\:01\:10.0/iommu_group/devices/
   [...] 0000:00:1e.0 -> ../../../../devices/pci0000:00/0000:00:1e.0
   [...] 0000:01:10.0 -> ../../../../devices/pci0000:00/0000:00:1e.0/0000:01:10.0
   [...] 0000:01:10.1 -> ../../../../devices/pci0000:00/0000:00:1e.0/0000:01:10.1
   ```

3. Unbind the device from the device driver:

   ```
   > sudo echo "0000:01:10.0" > /sys/bus/pci/devices/0000\:01\:10.0/driver/unbind
   ```

4. Bind the device to the vfio-pci driver using the vendor ID from step 1:

   ```
   > sudo echo "8086 153a" > /sys/bus/pci/drivers/vfio-pci/new_id
   ```

   A new device `/dev/vfio/IOMMU_GROUP` is created as a result, `/dev/vfio/20` in this case.

5. Change the ownership of the newly created device:

   ```
   > sudo chown qemu.qemu /dev/vfio/DEVICE
   ```

6. Now run the VM Guest with the PCI device assigned.

   ```
   > sudo qemu-system-ARCH [...] -device
       vfio-pci,host=00:10.0,id=ID
   ```

Important: No hotplugging

As of openSUSE Leap 15.5, hotplugging of PCI devices passed to a VM Guest via VFIO is not supported.

You can find more detailed information on the *VFIO* driver in the `/usr/src/linux/Documentation/vfio.txt` file (package `kernel-source` needs to be installed).

32.3.5 VirtFS: sharing directories between host and guests

VM Guests normally run in a separate computing space—they are provided their own memory range, dedicated CPUs, and file system space. The ability to share parts of the VM Host Server's file system makes the virtualization environment more flexible by simplifying mutual data exchange. Network file systems, such as CIFS and NFS, have been the traditional way of sharing directories. But as they are not specifically designed for virtualization purposes, they suffer from major performance and feature issues.

KVM introduces a new optimized method called *VirtFS* (sometimes called "file system pass-through"). VirtFS uses a paravirtual file system driver, which avoids converting the guest application file system operations into block device operations, and then again into host file system operations.

You typically use VirtFS for the following situations:

- To access a shared directory from several guests, or to provide guest-to-guest file system access.
- To replace the virtual disk as the root file system to which the guest's RAM disk connects during the guest boot process.
- To provide storage services to different customers from a single host file system in a cloud environment.

32.3.5.1 Implementation

In QEMU, the implementation of VirtFS is simplified by defining two types of devices:

- `virtio-9p-pci` device which transports protocol messages and data between the host and the guest.
- `fsdev` device which defines the export file system properties, such as file system type and security model.

EXAMPLE 32.1: EXPORTING HOST'S FILE SYSTEM WITH VIRTFS

```
> sudo qemu-system-x86_64 [...] \
-fsdev local,id=exp1❶,path=/tmp/❷,security_model=mapped❸ \
-device virtio-9p-pci,fsdev=exp1❹,mount_tag=v_tmp❺
```

❶ Identification of the file system to be exported.

2. File system path on the host to be exported.
3. Security model to be used—`mapped` keeps the guest file system modes and permissions isolated from the host, while `none` invokes a “pass-through” security model in which permission changes on the guest's files are reflected on the host as well.
4. The exported file system ID defined before with `-fsdev id=` .
5. Mount tag used later on the guest to mount the exported file system.

Such an exported file system can be mounted on the guest as follows:

```
> sudo mount -t 9p -o trans=virtio v_tmp /mnt
```

where `v_tmp` is the mount tag defined earlier with `-device mount_tag=` and `/mnt` is the mount point where you want to mount the exported file system.

32.3.6 KSM: sharing memory pages between guests

Kernel Same Page Merging (*KSM*) is a Linux kernel feature that merges identical memory pages from multiple running processes into one memory region. Because KVM guests run as processes under Linux, *KSM* provides the memory overcommit feature to hypervisors for more efficient use of memory. Therefore, if you need to run multiple virtual machines on a host with limited memory, *KSM* may be helpful to you.

KSM stores its status information in the files under the `/sys/kernel/mm/ksm` directory:

```
> ls -1 /sys/kernel/mm/ksm
full_scans
merge_across_nodes
pages_shared
pages_sharing
pages_to_scan
pages_unshared
pages_volatile
run
sleep_millisecs
```

For more information on the meaning of the `/sys/kernel/mm/ksm/*` files, see `/usr/src/linux/Documentation/vm/ksm.txt` (package `kernel-source`).

To use *KSM*, do the following.

1. Although openSUSE Leap includes *KSM* support in the kernel, it is disabled by default. To enable it, run the following command:

   ```
   # echo 1 > /sys/kernel/mm/ksm/run
   ```

2. Now run several VM Guests under KVM and inspect the content of files `pages_sharing` and `pages_shared`, for example:

   ```
   > while [ 1 ]; do cat /sys/kernel/mm/ksm/pages_shared; sleep 1; done
   13522
   13523
   13519
   13518
   13520
   13520
   13528
   ```

33 Guest installation

The `libvirt`-based tools such as **`virt-manager`** and **`virt-install`** offer convenient interfaces to set up and manage virtual machines. They act as a kind of wrapper for the **`qemu-system-ARCH`** command. However, it is also possible to use **`qemu-system-ARCH`** directly without using `libvirt`-based tools.

Warning: **`qemu-system-ARCH`** and libvirt

*Virtual Machine*s created with **`qemu-system-ARCH`** are not visible for the `libvirt`-based tools.

33.1 Basic installation with **`qemu-system-ARCH`**

In the following example, a virtual machine for a SUSE Linux Enterprise Server 11 installation is created. For detailed information on the commands, refer to the respective man pages.

If you do not already have an image of a system that you want to run in a virtualized environment, you need to create one from the installation media. In such case, you need to prepare a hard disk image, and obtain an image of the installation media or the media itself.

Create a hard disk with **`qemu-img`**.

```
> qemu-img create❶ -f raw❷ /images/sles/hda❸ 8G❹
```

❶ The subcommand `create` tells **`qemu-img`** to create a new image.

❷ Specify the disk's format with the `-f` parameter.

❸ The full path to the image file.

❹ The size of the image—8 GB in this case. The image is created as a *Sparse image file* file that grows when the disk is filled with data. The specified size defines the maximum size to which the image file can grow.

After at least one hard disk image is created, you can set up a virtual machine with **`qemu-system-ARCH`** that boots into the installation system:

```
# qemu-system-x86_64 -name "sles"❶-machine accel=kvm -M pc❷ -m 768❸ \
-smp 2❹ -boot d❺ \
-drive file=/images/sles/hda,if=virtio,index=0,media=disk,format=raw❻ \
-drive file=/isos/SLE-15-SP5-Online-ARCH-GM-media1.iso,index=1,media=cdrom❼ \
-net nic,model=virtio,macaddr=52:54:00:05:11:11❽ -net user \
-vga cirrus❾ -balloon virtio❿
```

❶ Name of the virtual machine that is displayed in the window caption and be used for the VNC server. This name must be unique.

❷ Specifies the machine type. Use **qemu-system-ARCH** -M ? to display a list of valid parameters. pc is the default *Standard PC*.

❸ Maximum amount of memory for the virtual machine.

❹ Defines an SMP system with two processors.

❺ Specifies the boot order. Valid values are a, b (floppy 1 and 2), c (first hard disk), d (first CD-ROM), or n to p (Ether-boot from network adapter 1-3). Defaults to c.

❻ Defines the first (index=0) hard disk. It is accessed as a paravirtualized (if=virtio) drive in raw format.

❼ The second (index=1) image drive acts as a CD-ROM.

❽ Defines a paravirtualized (model=virtio) network adapter with the MAC address 52:54:00:05:11:11. Be sure to specify a unique MAC address, otherwise a network conflict may occur.

❾ Specifies the graphic card. If you specify none, the graphic card is disabled.

❿ Defines the paravirtualized balloon device that allows to dynamically change the amount of memory (up to the maximum value specified with the parameter -m).

After the installation of the guest operating system finishes, you can start the related virtual machine without the need to specify the CD-ROM device:

```
# qemu-system-x86_64 -name "sles" -machine type=pc,accel=kvm -m 768 \
-smp 2 -boot c \
-drive file=/images/sles/hda,if=virtio,index=0,media=disk,format=raw \
-net nic,model=virtio,macaddr=52:54:00:05:11:11 \
-vga cirrus -balloon virtio
```

33.2 Managing disk images with **qemu-img**

In the previous section (see *Section 33.1, “Basic installation with* **qemu-system-ARCH**”), we used the **qemu-img** command to create an image of a hard disk. You can, however, use **qemu-img** for general disk image manipulation. This section introduces **qemu-img** subcommands to help manage the disk images flexibly.

33.2.1 General information on qemu-img invocation

qemu-img uses subcommands (like **zypper** does) to do specific tasks. Each subcommand understands a different set of options. Certain options are general and used by more of these subcommands, while others are unique to the related subcommand. See the qemu-img manual page (**man 1 qemu-img**) for a list of all supported options. **qemu-img** uses the following general syntax:

```
> qemu-img subcommand [options]
```

and supports the following subcommands:

`create`

Creates a new disk image on the file system.

`check`

Checks an existing disk image for errors.

`compare`

Check if two images have the same content.

`map`

Dumps the metadata of the image file name and its backing file chain.

`amend`

Amends the image format specific options for the image file name.

`convert`

Converts an existing disk image to a new one in a different format.

`info`

Displays information about the relevant disk image.

`snapshot`

Manages snapshots of existing disk images.

`commit`

Applies changes made to an existing disk image.

`rebase`

Creates a new base image based on an existing image.

`resize`

Increases or decreases the size of an existing image.

33.2.2 Creating, converting, and checking disk images

This section describes how to create disk images, check their condition, convert a disk image from one format to another, and get detailed information about a particular disk image.

33.2.2.1 qemu-img create

Use **`qemu-img create`** to create a new disk image for your VM Guest operating system. The command uses the following syntax:

```
> qemu-img create -f fmt❶ -o options❷ fname❸ size❹
```

❶ The format of the target image. Supported formats are `raw` and `qcow2`.

❷ Some image formats support additional options to be passed on the command line. You can specify them here with the `-o` option. The `raw` image format supports only the `size` option, so it is possible to insert `-o size=8G` instead of adding the size option at the end of the command.

❸ Path to the target disk image to be created.

❹ Size of the target disk image (if not already specified with the `-o size=<image_size>` option. Optional suffixes for the image size are `K` (kilobyte), `M` (megabyte), `G` (gigabyte), or `T` (terabyte).

To create a new disk image `sles.raw` in the directory `/images` growing up to a maximum size of 4 GB, run the following command:

```
> qemu-img create -f raw -o size=4G /images/sles.raw
Formatting '/images/sles.raw', fmt=raw size=4294967296

> ls -l /images/sles.raw
-rw-r--r-- 1 tux users 4294967296 Nov 15 15:56 /images/sles.raw

> qemu-img info /images/sles.raw
image: /images/sles11.raw
file format: raw
virtual size: 4.0G (4294967296 bytes)
disk size: 0
```

As you can see, the *virtual* size of the newly created image is 4 GB, but the actual reported disk size is 0 as no data has been written to the image yet.

Tip: VM Guest images on the Btrfs file system

If you need to create a disk image on the Btrfs file system, you can use `nocow=on` to reduce the performance overhead created by the copy-on-write feature of Btrfs:

```
> qemu-img create -o nocow=on test.img 8G
```

If you, however, want to use copy-on-write (for example for creating snapshots or sharing them across virtual machines), then leave the command line without the `nocow` option.

33.2.2.2 qemu-img convert

Use **`qemu-img convert`** to convert disk images to another format. To get a complete list of image formats supported by QEMU, run **`qemu-img`** `-h` and look at the last line of the output. The command uses the following syntax:

```
> qemu-img convert -c❶ -f fmt❷ -O out_fmt❸ -o options❹ fname❺ out_fname❻
```

❶ Applies compression on the target disk image. Only `qcow` and `qcow2` formats support compression.

❷ The format of the source disk image. It is normally autodetected and can therefore be omitted.

❸ The format of the target disk image.

❹ Specify additional options relevant for the target image format. Use `-o ?` to view the list of options supported by the target image format.

❺ Path to the source disk image to be converted.

❻ Path to the converted target disk image.

```
> qemu-img convert -O vmdk /images/sles.raw \
/images/sles.vmdk

> ls -l /images/
-rw-r--r-- 1 tux users 4294967296 16. lis 10.50 sles.raw
-rw-r--r-- 1 tux users 2574450688 16. lis 14.18 sles.vmdk
```

To see a list of options relevant for the selected target image format, run the following command (replace `vmdk` with your image format):

```
> qemu-img convert -O vmdk /images/sles.raw \
/images/sles.vmdk -o ?
Supported options:
size             Virtual disk size
backing_file     File name of a base image
compat6          VMDK version 6 image
subformat        VMDK flat extent format, can be one of {monolithicSparse \
    (default) | monolithicFlat | twoGbMaxExtentSparse | twoGbMaxExtentFlat}
scsi             SCSI image
```

33.2.2.3 qemu-img check

Use **`qemu-img check`** to check the existing disk image for errors. Not all disk image formats support this feature. The command uses the following syntax:

```
> qemu-img check -f fmt❶ fname❷
```

❶ The format of the source disk image. It is normally autodetected and can therefore be omitted.

❷ Path to the source disk image to be checked.

If no error is found, the command returns no output. Otherwise, the type and number of errors found is shown.

```
> qemu-img check -f qcow2 /images/sles.qcow2
ERROR: invalid cluster offset=0x2af0000
[...]
ERROR: invalid cluster offset=0x34ab0000
378 errors were found on the image.
```

33.2.2.4 Increasing the size of an existing disk image

When creating a new image, you must specify its maximum size before the image is created (see *Section 33.2.2.1, “qemu-img create”*). After you have installed the VM Guest and have been using it for certain time, the initial size of the image may no longer be sufficient. In that case, add more space to it.

To increase the size of an existing disk image by 2 gigabytes, use:

```
> qemu-img resize /images/sles.raw +2GB
```

Note

You can resize the disk image using the formats `raw` and `qcow2`. To resize an image in another format, convert it to a supported format with **`qemu-img convert`** first.

The image now contains an empty space of 2 GB after the final partition. You can resize the existing partitions or add new ones.

33.2.2.5 Advanced options for the qcow2 file format

qcow2 is the main disk image format used by QEMU. Its size grows on demand, and the disk space is only allocated when it is needed by the virtual machine.

A qcow2 formatted file is organized in units of constant size. These units are called *clusters*. Viewed from the guest side, the virtual disk is also divided into clusters of the same size. QEMU defaults to 64 kB clusters, but you can specify a different value when creating a new image:

```
> qemu-img create -f qcow2 -o cluster_size=128K virt_disk.qcow2 4G
```

A qcow2 image contains a set of tables organized in two levels that are called the L1 and L2 tables. There is just one L1 table per disk image, while there can be many L2 tables depending on how big the image is.

To read or write data to the virtual disk, QEMU needs to read its corresponding L2 table to find out the relevant data location. Because reading the table for each I/O operation consumes system resources, QEMU keeps a cache of L2 tables in memory to speed up disk access.

33.2.2.5.1 Choosing the right cache size

The cache size relates to the amount of allocated space. L2 cache can map the following amount of virtual disk:

```
disk_size = l2_cache_size * cluster_size / 8
```

With the default 64 kB of cluster size, that is

```
disk_size = l2_cache_size * 8192
```

Therefore, to have a cache that maps `n` gigabytes of disk space with the default cluster size, you need

```
l2_cache_size = disk_size_GB * 131072
```

QEMU uses 1 MB (1048576 bytes) of L2 cache by default. Following the above formulas, 1 MB of L2 cache covers 8 GB (1048576 / 131072) of virtual disk. This means that the performance is fine with the default L2 cache size if your virtual disk size is up to 8 GB. For larger disks, you can speed up the disk access by increasing the L2 cache size.

33.2.2.5.2 Configuring the cache size

You can use the `-drive` option on the QEMU command line to specify the cache sizes. Alternatively when communicating via QMP, use the **`blockdev-add`** command. For more information on QMP, see *Section 35.11, “QMP - QEMU machine protocol”*.

The following options configure the cache size for the virtual guest:

l2-cache-size

The maximum size of the L2 table cache.

refcount-cache-size

The maximum size of the *refcount* block cache. For more information on *refcount*, see https://raw.githubusercontent.com/qemu/qemu/master/docs/qcow2-cache.txt.

cache-size

The maximum size of both caches combined.

When specifying values for the options above, be aware of the following:

- The size of both the L2 and refcount block caches needs to be a multiple of the cluster size.
- If you only set one of the options, QEMU automatically adjusts the other options so that the L2 cache is 4 times bigger than the refcount cache.

The refcount cache is used much less often than the L2 cache, therefore you can keep it small:

```
# qemu-system-ARCH [...] \
 -drive file=disk_image.qcow2,l2-cache-size=4194304,refcount-cache-size=262144
```

33.2.2.5.3 Reducing the memory usage

The larger the cache, the more memory it consumes. There is a separate L2 cache for each qcow2 file. When using a lot of big disk images, you may need a considerably large amount of memory. Memory consumption is even worse if you add backing files (*Section 33.2.4, "Manipulate disk images effectively"*) and snapshots (see *Section 33.2.3, "Managing snapshots of virtual machines with qemu-img"*) to the guest's setup chain.

That is why QEMU introduced the `cache-clean-interval` setting. It defines an interval in seconds after which all cache entries that have not been accessed are removed from memory.

The following example removes all unused cache entries every 10 minutes:

```
# qemu-system-ARCH [...] -drive file=hd.qcow2,cache-clean-interval=600
```

If this option is not set, the default value is 0 and it disables this feature.

33.2.3 Managing snapshots of virtual machines with qemu-img

Virtual Machine snapshots are snapshots of the complete environment in which a VM Guest is running. The snapshot includes the state of the processor (CPU), memory (RAM), devices, and all writable disks.

Snapshots are helpful when you need to save your virtual machine in a particular state. For example, after you configured network services on a virtualized server and want to quickly start the virtual machine in the same state you last saved it. Or you can create a snapshot after the virtual machine has been powered off to create a backup state before you try something experimental and make VM Guest unstable. This section introduces the latter case, while the former is described in *Chapter 35, Virtual machine administration using QEMU monitor*.

To use snapshots, your VM Guest must contain at least one writable hard disk image in `qcow2` format. This device is normally the first virtual hard disk.

Virtual Machine snapshots are created with the `savevm` command in the interactive QEMU monitor. To make identifying a particular snapshot easier, you can assign it a *tag*. For more information on QEMU monitor, see *Chapter 35, Virtual machine administration using QEMU monitor*.

Once your `qcow2` disk image contains saved snapshots, you can inspect them with the **`qemu-img snapshot`** command.

Warning: Shut down the VM Guest

Do not create or delete virtual machine snapshots with the `qemu-img snapshot` command while the virtual machine is running. Otherwise, you may damage the disk image with the state of the virtual machine saved.

33.2.3.1 Listing existing snapshots

Use **`qemu-img snapshot -l`** *`DISK_IMAGE`* to view a list of all existing snapshots saved in the `disk_image` image. You can get the list even while the VM Guest is running.

```
> qemu-img snapshot -l /images/sles.qcow2
Snapshot list:
ID❶        TAG❷                VM SIZE❸          DATE❹           VM CLOCK❺
1         booting                  4.4M 2013-11-22 10:51:10   00:00:20.476
2         booted                   184M 2013-11-22 10:53:03   00:02:05.394
3         logged_in                273M 2013-11-22 11:00:25   00:04:34.843
4         ff_and_term_running      372M 2013-11-22 11:12:27   00:08:44.965
```

❶ Unique auto-incremented identification number of the snapshot.

❷ Unique description string of the snapshot. It is meant as a human-readable version of the ID.

❸ The disk space occupied by the snapshot. Note that the more memory is consumed by running applications, the bigger the snapshot is.

❹ Time and date the snapshot was created.

❺ The current state of the virtual machine's clock.

33.2.3.2 Creating snapshots of a powered-off virtual machine

Use **`qemu-img snapshot -c`** *`SNAPSHOT_TITLE`* *`DISK_IMAGE`* to create a snapshot of the current state of a virtual machine that was previously powered off.

```
> qemu-img snapshot -c backup_snapshot /images/sles.qcow2
```

```
> qemu-img snapshot -l /images/sles.qcow2
Snapshot list:
ID        TAG                 VM SIZE                DATE       VM CLOCK
1         booting                  4.4M 2013-11-22 10:51:10   00:00:20.476
2         booted                   184M 2013-11-22 10:53:03   00:02:05.394
3         logged_in                273M 2013-11-22 11:00:25   00:04:34.843
```

```
4         ff_and_term_running    372M 2013-11-22 11:12:27   00:08:44.965
5         backup_snapshot           0 2013-11-22 14:14:00   00:00:00.000
```

If something breaks in your VM Guest and you need to restore the state of the saved snapshot (ID 5 in our example), power off your VM Guest and execute the following command:

```
> qemu-img snapshot -a 5 /images/sles.qcow2
```

The next time you run the virtual machine with **`qemu-system-ARCH`**, it will be in the state of snapshot number 5.

Note

The **`qemu-img snapshot -c`** command is not related to the `savevm` command of QEMU monitor (see *Chapter 35, Virtual machine administration using QEMU monitor*). For example, you cannot apply a snapshot with **`qemu-img snapshot -a`** on a snapshot created with `savevm` in QEMU's monitor.

33.2.3.3 Deleting snapshots

Use **`qemu-img snapshot -d`** *`SNAPSHOT_ID`* *`DISK_IMAGE`* to delete old or unneeded snapshots of a virtual machine. This saves disk space inside the `qcow2` disk image as the space occupied by the snapshot data is restored:

```
> qemu-img snapshot -d 2 /images/sles.qcow2
```

33.2.4 Manipulate disk images effectively

Imagine the following real-life situation: you are a server administrator who runs and manages several virtualized operating systems. One group of these systems is based on one specific distribution, while another group (or groups) is based on different versions of the distribution or even on a different (and maybe non-Unix) platform. To make the case even more complex, individual virtual guest systems based on the same distribution differ according to the department and deployment. A file server typically uses a different setup and services than a Web server does, while both may still be based on openSUSE.

With QEMU it is possible to create “base” disk images. You can use them as template virtual machines. These base images save you plenty of time because you do not need to install the same operating system more than once.

33.2.4.1 Base and derived images

First, build a disk image as usual and install the target system on it. For more information, see *Section 33.1, "Basic installation with* **`qemu-system-ARCH`***"* and *Section 33.2.2, "Creating, converting, and checking disk images"*. Then build a new image while using the first one as a base image. The base image is also called a *backing* file. After your new *derived* image is built, never boot the base image again, but boot the derived image instead. Several derived images may depend on one base image at the same time. Therefore, changing the base image can damage the dependencies. While using your derived image, QEMU writes changes to it and uses the base image only for reading.

It is a good practice to create a base image from a freshly installed (and, if needed, registered) operating system with no patches applied and no additional applications installed or removed. Later on, you can create another base image with the latest patches applied and based on the original base image.

33.2.4.2 Creating derived images

Note

While you can use the `raw` format for base images, you cannot use it for derived images because the `raw` format does not support the `backing_file` option. Use for example the `qcow2` format for the derived images.

For example, `/images/sles_base.raw` is the base image holding a freshly installed system.

```
> qemu-img info /images/sles_base.raw
image: /images/sles_base.raw
file format: raw
virtual size: 4.0G (4294967296 bytes)
disk size: 2.4G
```

The image's reserved size is 4 GB, the actual size is 2.4 GB, and its format is `raw`. Create an image derived from the `/images/sles_base.raw` base image with:

```
> qemu-img create -f qcow2 /images/sles_derived.qcow2 \
-o backing_file=/images/sles_base.raw
Formatting '/images/sles_derived.qcow2', fmt=qcow2 size=4294967296 \
backing_file='/images/sles_base.raw' encryption=off cluster_size=0
```

Look at the derived image details:

```
> qemu-img info /images/sles_derived.qcow2
image: /images/sles_derived.qcow2
file format: qcow2
virtual size: 4.0G (4294967296 bytes)
disk size: 140K
cluster_size: 65536
backing file: /images/sles_base.raw \
(actual path: /images/sles_base.raw)
```

Although the reserved size of the derived image is the same as the size of the base image (4 GB), the actual size is 140 KB only. The reason is that only changes made to the system inside the derived image are saved. Run the derived virtual machine, register it, if needed, and apply the latest patches. Do any other changes in the system such as removing unneeded or installing new software packages. Then shut the VM Guest down and examine its details once more:

```
> qemu-img info /images/sles_derived.qcow2
image: /images/sles_derived.qcow2
file format: qcow2
virtual size: 4.0G (4294967296 bytes)
disk size: 1.1G
cluster_size: 65536
backing file: /images/sles_base.raw \
(actual path: /images/sles_base.raw)
```

The `disk size` value has grown to 1.1 GB, which is the disk space occupied by the changes on the file system compared to the base image.

33.2.4.3 Rebasing derived images

After you have modified the derived image (applied patches, installed specific applications, changed environment settings, etc.), it reaches the desired state. At that point, you can merge the original base image and the derived image to create a new base image.

Your original base image (`/images/sles_base.raw`) holds a freshly installed system. It can be a template for new modified base images, while the new one can contain the same system as the first one plus all security and update patches applied, for example. After you have created this new base image, you can use it as a template for more specialized derived images as well. The new base image becomes independent of the original one. The process of creating base images from derived ones is called *rebasing*:

```
> qemu-img convert /images/sles_derived.qcow2 \
-O raw /images/sles_base2.raw
```

This command created the new base image `/images/sles_base2.raw` using the `raw` format.

```
> qemu-img info /images/sles_base2.raw
image: /images/sles11_base2.raw
file format: raw
virtual size: 4.0G (4294967296 bytes)
disk size: 2.8G
```

The new image is 0.4 gigabytes bigger than the original base image. It uses no backing file, and you can easily create new derived images based upon it. This lets you create a sophisticated hierarchy of virtual disk images for your organization, saving a lot of time and work.

33.2.4.4 Mounting an image on a VM Host Server

It can be useful to mount a virtual disk image under the host system. It is strongly recommended to read *Chapter 18, libguestfs* and use dedicated tools to access a virtual machine image. However, if you need to do this manually, follow this guide.

Linux systems can mount an internal partition of a `raw` disk image using a loopback device. The first example procedure is more complex but more illustrative, while the second one is straightforward:

PROCEDURE 33.1: MOUNTING DISK IMAGE BY CALCULATING PARTITION OFFSET

1. Set a *loop* device on the disk image whose partition you want to mount.

   ```
   > losetup /dev/loop0 /images/sles_base.raw
   ```

2. Find the *sector size* and the starting *sector number* of the partition you want to mount.

   ```
   > fdisk -lu /dev/loop0

   Disk /dev/loop0: 4294 MB, 4294967296 bytes
   255 heads, 63 sectors/track, 522 cylinders, total 8388608 sectors
   Units = sectors of 1 * 512 = 512❶ bytes
   Disk identifier: 0x000ceca8

          Device Boot      Start         End      Blocks   Id  System
   /dev/loop0p1               63     1542239      771088+  82  Linux swap
   /dev/loop0p2   *      1542240❷     8385929     3421845   83  Linux
   ```

   ❶ The disk sector size.

❷ The starting sector of the partition.

3. Calculate the partition start offset:

   `sector_size * sector_start = 512 * 1542240 = 789626880`

4. Delete the loop and mount the partition inside the disk image with the calculated offset on a prepared directory.

   ```
   > losetup -d /dev/loop0
   > mount -o loop,offset=789626880 \
   /images/sles_base.raw /mnt/sles/
   > ls -l /mnt/sles/
   total 112
   drwxr-xr-x   2 root root  4096 Nov 16 10:02 bin
   drwxr-xr-x   3 root root  4096 Nov 16 10:27 boot
   drwxr-xr-x   5 root root  4096 Nov 16 09:11 dev
   [...]
   drwxrwxrwt  14 root root  4096 Nov 24 09:50 tmp
   drwxr-xr-x  12 root root  4096 Nov 16 09:16 usr
   drwxr-xr-x  15 root root  4096 Nov 16 09:22 var
   ```

5. Copy one or more files onto the mounted partition and unmount it when finished.

   ```
   > cp /etc/X11/xorg.conf /mnt/sles/root/tmp
   > ls -l /mnt/sles/root/tmp
   > umount /mnt/sles/
   ```

Warning: Do not write to images currently in use

Never mount a partition of an image of a running virtual machine in a `read-write` mode. This could corrupt the partition and break the whole VM Guest.

34 Running virtual machines with qemu-system-ARCH

Once you have a virtual disk image ready (for more information on disk images, see *Section 33.2, “Managing disk images with* **`qemu-img`***”*), it is time to start the related virtual machine. *Section 33.1, “Basic installation with* **`qemu-system-ARCH`***”* introduced simple commands to install and run a VM Guest. This chapter focuses on a more detailed explanation of **`qemu-system-ARCH`** usage, and shows solutions for more specific tasks. For a complete list of **`qemu-system-ARCH`**'s options, see its manual page (**`man 1 qemu`**).

34.1 Basic `qemu-system-ARCH` invocation

The **`qemu-system-ARCH`** command uses the following syntax:

```
qemu-system-ARCH OPTIONS❶ -drive file=DISK_IMAGE❷
```

❶ **`qemu-system-ARCH`** understands many options. Most of them define parameters of the emulated hardware, while others affect more general emulator behavior. If you do not supply any options, default values are used, and you need to supply the path to a disk image to be run.

❷ Path to the disk image holding the guest system you want to virtualize. **`qemu-system-ARCH`** supports many image formats. Use **`qemu-img`** `--help` to list them.

Important: AArch64 architecture

KVM support is available only for 64-bit ARM architecture (AArch64). Running QEMU on the AArch64 architecture requires you to specify:

- A machine type designed for QEMU ARM virtual machines using the `-machine virt-`*`VERSION_NUMBER`* option.
- A firmware image file using the `-bios` option.
  You can specify the firmware image files alternatively using the `-drive` options, for example:

  ```
  -drive file=/usr/share/edk2/aarch64/QEMU_EFI-pflash.raw,if=pflash,format=raw
  -drive file=/var/lib/libvirt/qemu/nvram/opensuse_VARS.fd,if=pflash,format=raw
  ```

- A CPU of the VM Host Server using the `-cpu host` option (default is `cortex-15`).
- The same Generic Interrupt Controller (GIC) version as the host using the `-machine gic-version=host` option (default is `2`).
- If a graphic mode is needed, a graphic device of type `virtio-gpu-pci`.

For example:

```
> sudo qemu-system-aarch64 [...] \
 -bios /usr/share/qemu/qemu-uefi-aarch64.bin \
 -cpu host \
 -device virtio-gpu-pci \
 -machine virt,accel=kvm,gic-version=host
```

34.2 General **qemu-system-ARCH** options

This section introduces general **`qemu-system-ARCH`** options and options related to the basic emulated hardware, such as the virtual machine's processor, memory, model type, or time processing methods.

`-name` *`NAME_OF_GUEST`*

Specifies the name of the running guest system. The name is displayed in the window caption and used for the VNC server.

`-boot` *`OPTIONS`*

Specifies the order in which the defined drives are booted. Drives are represented by letters, where `a` and `b` stand for the floppy drives 1 and 2, `c` stands for the first hard disk, `d` stands for the first CD-ROM drive, and `n` to `p` stand for Ether-boot network adapters.

For example, `qemu-system-ARCH [...] -boot order=ndc` first tries to boot from the network, then from the first CD-ROM drive, and finally from the first hard disk.

`-pidfile` *`FILENAME`*

Stores the QEMU's process identification number (PID) in a file. This is useful if you run QEMU from a script.

`-nodefaults`

By default QEMU creates basic virtual devices even if you do not specify them on the command line. This option turns this feature off, and you must specify every single device manually, including graphical and network cards, parallel or serial ports, or virtual consoles. Even QEMU monitor is not attached by default.

`-daemonize`

"Daemonizes" the QEMU process after it is started. QEMU detaches from the standard input and standard output after it is ready to receive connections on any of its devices.

Note: SeaBIOS BIOS implementation

SeaBIOS is the default BIOS used. You can boot USB devices, any drive (CD-ROM, Floppy or a hard disk). It has USB mouse and keyboard support and supports multiple VGA cards. For more information about SeaBIOS, refer to the SeaBIOS Website (https://www.seabios.org/SeaBIOS) ↗.

34.2.1 Basic virtual hardware

34.2.1.1 Machine type

You can specify the type of the emulated machine. Run **`qemu-system-ARCH -M help`** to view a list of supported machine types.

Note: ISA-PC

The machine type *isapc: ISA-only-PC* is unsupported.

34.2.1.2 CPU model

To specify the type of the processor (CPU) model, run **`qemu-system-ARCH -cpu`** *`MODEL`*. Use **`qemu-system-ARCH -cpu help`** to view a list of supported CPU models.

34.2.1.3 Other basic options

The following is a list of most commonly used options while launching *qemu* from command line. To see all options available refer to *qemu-doc* man page.

`-m MEGABYTES`

Specifies how many megabytes are used for the virtual RAM size.

`-balloon virtio`

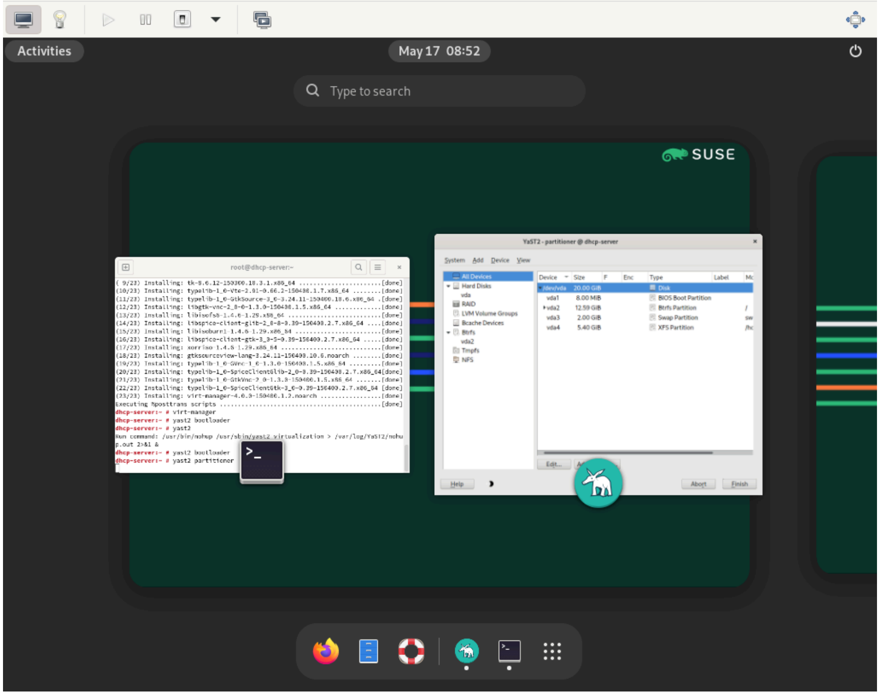
Specifies a paravirtualized device to dynamically change the amount of virtual RAM assigned to VM Guest. The top limit is the amount of memory specified with `-m`.

`-smp NUMBER_OF_CPUS`

Specifies how many CPUs to emulate. QEMU supports up to 255 CPUs on the PC platform (up to 64 with KVM acceleration used). This option also takes other CPU-related parameters, such as number of *sockets*, number of *cores* per socket, or number of *threads* per core.

The following is an example of a working **`qemu-system-ARCH`** command line:

```
> sudo qemu-system-x86_64 \
 -name "SLES 15.5" \
 -M pc-i440fx-2.7 -m 512 \
 -machine accel=kvm -cpu kvm64 -smp 2 \
 -drive format=raw,file=/images/sles.raw
```



root@dhcp-server:~

```
( 9/23) Installing: tk-8.6.12-150300.10.3.1.x86_64 .......................[done]
(10/23) Installing: typelib-1_0-Vte-2.91-0.66.2-150400.1.7.x86_64 ........[done]
(11/23) Installing: typelib-1_0-GtkSource-3_0-3.24.11-150400.10.6.x86_64 .[done]
(12/23) Installing: libgtk-vnc-2_0-0-1.3.0-150400.1.5.x86_64 .............[done]
(13/23) Installing: libisofs6-1.4.6-1.29.x86_64 ..........................[done]
(14/23) Installing: libspice-client-glib-2_0-8-0.39-150400.2.7.x86_64 ....[done]
(15/23) Installing: libisoburn1-1.4.6-1.29.x86_64 ........................[done]
(16/23) Installing: libspice-client-gtk-3_0-5-0.39-150400.2.7.x86_64 .....[done]
(17/23) Installing: xorriso-1.4.6-1.29.x86_64 ............................[done]
(18/23) Installing: gtksourceview-lang-3.24.11-150400.10.6.noarch ........[done]
(19/23) Installing: typelib-1_0-GVnc-1_0-1.3.0-150400.1.5.x86_64 .........[done]
(20/23) Installing: typelib-1_0-SpiceClientGlib-2_0-0.39-150400.2.7.x86_64[done]
(21/23) Installing: typelib-1_0-GtkVnc-2_0-1.3.0-150400.1.5.x86_64 .......[done]
(22/23) Installing: typelib-1_0-SpiceClientGtk-3_0-0.39-150400.2.7.x86_64 [done]
(23/23) Installing: virt-manager-4.0.0-150400.1.2.noarch .................[done]
Executing %posttrans scripts .............................................[done]
dhcp-server:~ # virt-manager
dhcp-server:~ # yast2 bootloader
dhcp-server:~ # yast2
Run command: /usr/bin/nohup /usr/sbin/yast2 virtualization > /var/log/YaST2/nohu
p.out 2>&1 &
dhcp-server:~ # yast2 bootloader
dhcp-server:~ # yast2 partitioner
```

YaST2 - partitioner @ dhcp-server

Device	Size	F	Enc	Type	Label	Mc
/dev/vda	20.00 GiB			Disk		
vda1	8.00 MiB			BIOS Boot Partition		
vda2	12.59 GiB			Btrfs Partition		/
vda3	2.00 GiB			Swap Partition		sw
vda4	5.40 GiB			XFS Partition		/hc

FIGURE 34.1: QEMU WINDOW WITH SLES AS VM GUEST

`-no-acpi`

Disables *ACPI* support.

`-S`

QEMU starts with CPU stopped. To start CPU, enter `c` in QEMU monitor. For more information, see *Chapter 35, Virtual machine administration using QEMU monitor*.

34.2.2 Storing and reading configuration of virtual devices

`-readconfig` *`CFG_FILE`*

Instead of entering the devices configuration options on the command line each time you want to run VM Guest, **`qemu-system-ARCH`** can read it from a file that was either previously saved with `-writeconfig` or edited manually.

`-writeconfig` *`CFG_FILE`*

Dumps the current virtual machine's devices configuration to a text file. It can be consequently re-used with the `-readconfig` option.

```
> sudo qemu-system-x86_64 -name "SLES 15.5" \
 -machine accel=kvm -M pc-i440fx-2.7 -m 512 -cpu kvm64 \
 -smp 2 /images/sles.raw -writeconfig /images/sles.cfg
(exited)
> cat /images/sles.cfg
# qemu config file

[drive]
  index = "0"
  media = "disk"
  file = "/images/sles_base.raw"
```

This way you can effectively manage the configuration of your virtual machines' devices in a well-arranged way.

34.2.3 Guest real-time clock

`-rtc` *`OPTIONS`*

Specifies the way the RTC is handled inside a VM Guest. By default, the clock of the guest is derived from that of the host system. Therefore, it is recommended that the host system clock is synchronized with an accurate external clock (for example, via NTP service).

If you need to isolate the VM Guest clock from the host one, specify `clock=vm` instead of the default `clock=host`.
You can also specify the initial time of the VM Guest's clock with the `base` option:

```
> sudo qemu-system-x86_64 [...] -rtc clock=vm,base=2010-12-03T01:02:00
```

Instead of a time stamp, you can specify `utc` or `localtime`. The former instructs VM Guest to start at the current UTC value (Coordinated Universal Time, see http://en.wikipedia.org/wiki/UTC ↗), while the latter applies the local time setting.

34.3 Using devices in QEMU

QEMU virtual machines emulate all devices needed to run a VM Guest. QEMU supports, for example, several types of network cards, block devices (hard and removable drives), USB devices, character devices (serial and parallel ports), or multimedia devices (graphic and sound cards). This section introduces options to configure multiple types of supported devices.

Tip

If your device, such as `-drive`, needs a special driver and driver properties to be set, specify them with the `-device` option, and identify with `drive=` suboption. For example:

```
> sudo qemu-system-x86_64 [...] -drive if=none,id=drive0,format=raw \
-device virtio-blk-pci,drive=drive0,scsi=off ...
```

To get help on available drivers and their properties, use `-device ?` and `-device DRIVER,?`.

34.3.1 Block devices

Block devices are vital for virtual machines. These are fixed or removable storage media called *drives*. One of the connected hard disks typically holds the guest operating system to be virtualized.

Virtual Machine drives are defined with `-drive`. This option has many sub-options, so me of which are described in this section. For the complete list, see the manual page (**`man 1 qemu`**).

SUB-OPTIONS FOR THE `-drive` OPTION

`file=image_fname`

Specifies the path to the disk image that to be used with this drive. If not specified, an empty (removable) drive is assumed.

`if=drive_interface`

Specifies the type of interface to which the drive is connected. Currently only `floppy`, `scsi`, `ide`, or `virtio` are supported by SUSE. `virtio` defines a paravirtualized disk driver. Default is `ide`.

`index=index_of_connector`

Specifies the index number of a connector on the disk interface (see the `if` option) where the drive is connected. If not specified, the index is automatically incremented.

`media=type`

Specifies the type of media. Can be `disk` for hard disks, or `cdrom` for removable CD-ROM drives.

`format=img_fmt`

Specifies the format of the connected disk image. If not specified, the format is autodetected. Currently, SUSE supports `raw` and `qcow2` formats.

`cache=method`

Specifies the caching method for the drive. Possible values are `unsafe`, `writethrough`, `writeback`, `directsync`, or `none`. To improve performance when using the `qcow2` image format, select `writeback`. `none` disables the host page cache and, therefore, is the safest option. Default for image files is `writeback`. For more information, see *Chapter 16, Disk cache modes*.

Tip

To simplify defining block devices, QEMU understands several shortcuts which you may find handy when entering the `qemu-system-ARCH` command line.

You can use

```
> sudo qemu-system-x86_64 -cdrom /images/cdrom.iso
```

instead of

```
> sudo qemu-system-x86_64 -drive format=raw,file=/images/
cdrom.iso,index=2,media=cdrom
```

and

```
> sudo qemu-system-x86_64 -hda /images/imagei1.raw -hdb /images/image2.raw -hdc \
/images/image3.raw -hdd /images/image4.raw
```

instead of

```
> sudo qemu-system-x86_64 -drive format=raw,file=/images/
image1.raw,index=0,media=disk \
-drive format=raw,file=/images/image2.raw,index=1,media=disk \
-drive format=raw,file=/images/image3.raw,index=2,media=disk \
-drive format=raw,file=/images/image4.raw,index=3,media=disk
```

Tip: Using host drives instead of images

As an alternative to using disk images (see *Section 33.2, “Managing disk images with* **qemu-img***”*) you can also use existing VM Host Server disks, connect them as drives, and access them from VM Guest. Use the host disk device directly instead of disk image file names.

To access the host CD-ROM drive, use

```
> sudo qemu-system-x86_64 [...] -drive file=/dev/cdrom,media=cdrom
```

To access the host hard disk, use

```
> sudo qemu-system-x86_64 [...] -drive file=/dev/hdb,media=disk
```

A host drive used by a VM Guest must not be accessed concurrently by the VM Host Server or another VM Guest.

34.3.1.1 Freeing unused guest disk space

A *Sparse image file* is a type of disk image file that grows in size as the user adds data to it, taking up only as much disk space as is stored in it. For example, if you copy 1 GB of data inside the sparse disk image, its size grows by 1 GB. If you then delete for example 500 MB of the data, the image size does not by default decrease as expected.

That is why the `discard=on` option is introduced on the KVM command line. It tells the hypervisor to automatically free the "holes" after deleting data from the sparse guest image. Note that this option is valid only for the `if=scsi` drive interface:

```
> sudo qemu-system-x86_64 [...] -drive format=img_format,file=/path/to/
file.img,if=scsi,discard=on
```

Important: Support status

`if=scsi` is not supported. This interface does not map to *virtio-scsi*, but rather to the *lsi SCSI adapter*.

34.3.1.2 IOThreads

IOThreads are dedicated event loop threads for virtio devices to perform I/O requests to improve scalability, especially on an SMP VM Host Server with SMP VM Guests using many disk devices. Instead of using QEMU's main event loop for I/O processing, IOThreads allow spreading I/O work across multiple CPUs and can improve latency when properly configured.

IOThreads are enabled by defining IOThread objects. virtio devices can then use the objects for their I/O event loops. Many virtio devices can use a single IOThread object, or virtio devices and IOThread objects can be configured in a 1:1 mapping. The following example creates a single IOThread with ID `iothread0` which is then used as the event loop for two virtio-blk devices.

```
> sudo qemu-system-x86_64 [...] -object iothread,id=iothread0\
-drive if=none,id=drive0,cache=none,aio=native,\
format=raw,file=filename -device virtio-blk-pci,drive=drive0,scsi=off,\
iothread=iothread0 -drive if=none,id=drive1,cache=none,aio=native,\
format=raw,file=filename -device virtio-blk-pci,drive=drive1,scsi=off,\
iothread=iothread0 [...]
```

The following qemu command line example illustrates a 1:1 virtio device to IOThread mapping:

```
> sudo qemu-system-x86_64 [...] -object iothread,id=iothread0\
-object iothread,id=iothread1 -drive if=none,id=drive0,cache=none,aio=native,\
format=raw,file=filename -device virtio-blk-pci,drive=drive0,scsi=off,\
iothread=iothread0 -drive if=none,id=drive1,cache=none,aio=native,\
format=raw,file=filename -device virtio-blk-pci,drive=drive1,scsi=off,\
    iothread=iothread1 [...]
```

34.3.1.3 Bio-based I/O path for virtio-blk

For better performance of I/O-intensive applications, a new I/O path was introduced for the virtio-blk interface in kernel version 3.7. This bio-based block device driver skips the I/O scheduler, and thus shortens the I/O path in guest and has lower latency. It is especially useful for high-speed storage devices, such as SSD disks.

The driver is disabled by default. To use it, do the following:

1. Append `virtio_blk.use_bio=1` to the kernel command line on the guest. You can do so via *YaST* › *System* › *Boot Loader*.
   You can do it also by editing `/etc/default/grub`, searching for the line that contains `GRUB_CMDLINE_LINUX_DEFAULT=`, and adding the kernel parameter at the end. Then run **`grub2-mkconfig >/boot/grub2/grub.cfg`** to update the grub2 boot menu.

2. Reboot the guest with the new kernel command line active.

Tip: Bio-based driver on slow devices

The bio-based virtio-blk driver does not help on slow devices such as spin hard disks. The reason is that the benefit of scheduling is larger than what the shortened bio path offers. Do not use the bio-based driver on slow devices.

34.3.1.4 Accessing iSCSI resources directly

QEMU now integrates with `libiscsi`. This allows QEMU to access iSCSI resources directly and use them as virtual machine block devices. This feature does not require any host iSCSI initiator configuration, as is needed for a libvirt iSCSI target based storage pool setup. Instead it directly connects guest storage interfaces to an iSCSI target LUN via the user space library libiscsi. iSCSI-based disk devices can also be specified in the libvirt XML configuration.

Note: RAW image format

This feature is only available using the RAW image format, as the iSCSI protocol has certain technical limitations.

The following is the QEMU command line interface for iSCSI connectivity.

Note: virt-manager limitation

The use of libiscsi based storage provisioning is not yet exposed by the virt-manager interface, but instead it would be configured by directly editing the guest xml. This new way of accessing iSCSI based storage is to be done at the command line.

```
> sudo qemu-system-x86_64 -machine accel=kvm \
  -drive file=iscsi://192.168.100.1:3260/iqn.2016-08.com.example:314605ab-a88e-49af-
b4eb-664808a3443b/0,\
  format=raw,if=none,id=mydrive,cache=none \
  -device ide-hd,bus=ide.0,unit=0,drive=mydrive ...
```

Here is an example snippet of guest domain xml which uses the protocol based iSCSI:

```
<devices>
...
  <disk type='network' device='disk'>
    <driver name='qemu' type='raw'/>
    <source protocol='iscsi' name='iqn.2013-07.com.example:iscsi-nopool/2'>
      <host name='example.com' port='3260'/>
    </source>
    <auth username='myuser'>
      <secret type='iscsi' usage='libvirtiscsi'/>
    </auth>
    <target dev='vda' bus='virtio'/>
  </disk>
</devices>
```

Contrast that with an example which uses the host based iSCSI initiator which virt-manager sets up:

```
<devices>
...
  <disk type='block' device='disk'>
    <driver name='qemu' type='raw' cache='none' io='native'/>
    <source dev='/dev/disk/by-path/scsi-0:0:0:0'/>
    <target dev='hda' bus='ide'/>
    <address type='drive' controller='0' bus='0' target='0' unit='0'/>
  </disk>
  <controller type='ide' index='0'>
    <address type='pci' domain='0x0000' bus='0x00' slot='0x01'
             function='0x1'/>
  </controller>
</devices>
```

34.3.1.5 Using RADOS block devices with QEMU

RADOS Block Devices (RBD) store data in a Ceph cluster. They allow snapshotting, replication and data consistency. You can use an RBD from your KVM-managed VM Guests similarly to how you use other block devices.

34.3.2 Graphic devices and display options

This section describes QEMU options affecting the type of the emulated video card and the way VM Guest graphical output is displayed.

34.3.2.1 Defining video cards

QEMU uses `-vga` to define a video card used to display VM Guest graphical output. The `-vga` option understands the following values:

`none`

Disables video cards on VM Guest (no video card is emulated). You can still access the running VM Guest via the serial console.

`std`

Emulates a standard VESA 2.0 VBE video card. Use it if you intend to use high display resolution on VM Guest.

qxl

QXL is a paravirtual graphic card. It is VGA compatible (including VESA 2.0 VBE support). `qxl` is recommended when using the `spice` video protocol.

virtio

Paravirtual VGA graphic card.

34.3.2.2 Display options

The following options affect the way VM Guest graphical output is displayed.

`-display gtk`

Display video output in a GTK window. This interface provides UI elements to configure and control the VM during runtime.

`-display sdl`

Display video output via SDL in a separate graphics window. For more information, see the SDL documentation.

`-spice option[,option[,...]]`

Enables the spice remote desktop protocol.

`-display vnc`

Refer to *Section 34.5, “Viewing a VM Guest with VNC”* for more information.

`-nographic`

Disables QEMU's graphical output. The emulated serial port is redirected to the console.

After starting the virtual machine with `-nographic`, press **Ctrl**–**A** **H** in the virtual console to view the list of other useful shortcuts, for example, to toggle between the console and the QEMU monitor.

```
> sudo qemu-system-x86_64 -hda /images/sles_base.raw -nographic

C-a h    print this help
C-a x    exit emulator
C-a s    save disk data back to file (if -snapshot)
C-a t    toggle console timestamps
C-a b    send break (magic sysrq)
C-a c    switch between console and monitor
C-a C-a  sends C-a
(pressed C-a c)

QEMU 2.3.1 monitor - type 'help' for more information
(qemu)
```

`-no-frame`

Disables decorations for the QEMU window. Convenient for dedicated desktop work space.

`-full-screen`

Starts QEMU graphical output in full screen mode.

`-no-quit`

Disables the close button of the QEMU window and prevents it from being closed by force.

`-alt-grab`, `-ctrl-grab`

By default, the QEMU window releases the “captured” mouse after pressing **Ctrl**–**Alt**. You can change the key combination to either **Ctrl**–**Alt**–**Shift** (`-alt-grab`), or the right **Ctrl** key (`-ctrl-grab`).

34.3.3 USB devices

There are two ways to create USB devices usable by the VM Guest in KVM: you can either emulate new USB devices inside a VM Guest, or assign an existing host USB device to a VM Guest. To use USB devices in QEMU you first need to enable the generic USB driver with the `-usb` option. Then you can specify individual devices with the `-usbdevice` option.

34.3.3.1 Emulating USB devices in VM Guest

SUSE currently supports the following types of USB devices: `disk`, `host`, `serial`, `braille`, `net`, `mouse`, and `tablet`.

TYPES OF USB DEVICES FOR THE `-usbdevice` OPTION

`disk`

Emulates a mass storage device based on file. The optional `format` option is used rather than detecting the format.

```
> sudo qemu-system-x86_64 [...] -usbdevice
        disk:format=raw:/virt/usb_disk.raw
```

`host`

Pass through the host device (identified by bus.addr).

`serial`

Serial converter to a host character device.

`braille`

Emulates a braille device using BrlAPI to display the braille output.

`net`

Emulates a network adapter that supports CDC Ethernet and RNDIS protocols.

`mouse`

Emulates a virtual USB mouse. This option overrides the default PS/2 mouse emulation. The following example shows the hardware status of a mouse on VM Guest started with `qemu-system-ARCH [...] -usbdevice mouse`:

```
> sudo hwinfo --mouse
20: USB 00.0: 10503 USB Mouse
[Created at usb.122]
UDI: /org/freedesktop/Hal/devices/usb_device_627_1_1_if0
```

```
[...]
Hardware Class: mouse
Model: "Adomax QEMU USB Mouse"
Hotplug: USB
Vendor: usb 0x0627 "Adomax Technology Co., Ltd"
Device: usb 0x0001 "QEMU USB Mouse"
[...]
```

`tablet`

Emulates a pointer device that uses absolute coordinates (such as touchscreen). This option overrides the default PS/2 mouse emulation. The tablet device is useful if you are viewing VM Guest via the VNC protocol. See *Section 34.5, "Viewing a VM Guest with VNC"* for more information.

34.3.4 Character devices

Use `-chardev` to create a new character device. The option uses the following general syntax:

```
qemu-system-x86_64 [...] -chardev BACKEND_TYPE,id=ID_STRING
```

where *BACKEND_TYPE* can be one of `null`, `socket`, `udp`, `msmouse`, `vc`, `file`, `pipe`, `console`, `serial`, `pty`, `stdio`, `braille`, `tty`, or `parport`. All character devices must have a unique identification string up to 127 characters long. It is used to identify the device in other related directives. For the complete description of all back-end's sub-options, see the manual page (**`man 1 qemu`**). A brief description of the available `back-ends` follows:

`null`

Creates an empty device that outputs no data and drops any data it receives.

`stdio`

Connects to QEMU's process standard input and standard output.

`socket`

Creates a two-way stream socket. If *PATH* is specified, a Unix socket is created:

```
> sudo qemu-system-x86_64 [...] -chardev \
socket,id=unix_socket1,path=/tmp/unix_socket1,server
```

The *SERVER* suboption specifies that the socket is a listening socket.
If *PORT* is specified, a TCP socket is created:

```
> sudo qemu-system-x86_64 [...] -chardev \
socket,id=tcp_socket1,host=localhost,port=7777,server,nowait
```

The command creates a local listening (`server`) TCP socket on port 7777. QEMU does not block waiting for a client to connect to the listening port (`nowait`).

`udp`

Sends all network traffic from VM Guest to a remote host over the UDP protocol.

```
> sudo qemu-system-x86_64 [...] \
-chardev udp,id=udp_fwd,host=mercury.example.com,port=7777
```

The command binds port 7777 on the remote host mercury.example.com and sends VM Guest network traffic there.

`vc`

Creates a new QEMU text console. You can optionally specify the dimensions of the virtual console:

```
> sudo qemu-system-x86_64 [...] -chardev vc,id=vc1,width=640,height=480 \
-mon chardev=vc1
```

The command creates a new virtual console called `vc1` of the specified size, and connects the QEMU monitor to it.

`file`

Logs all traffic from VM Guest to a file on VM Host Server. The `path` is required and is automatically created if it does not exist.

```
> sudo qemu-system-x86_64 [...] \
-chardev file,id=qemu_log1,path=/var/log/qemu/guest1.log
```

By default QEMU creates a set of character devices for serial and parallel ports, and a special console for QEMU monitor. However, you can create your own character devices and use them for the mentioned purposes. The following options may help you:

`-serial` *`CHAR_DEV`*

Redirects the VM Guest's virtual serial port to a character device *`CHAR_DEV`* on VM Host Server. By default, it is a virtual console (`vc`) in graphical mode, and `stdio` in non-graphical mode. The `-serial` understands many sub-options. See the manual page **`man 1 qemu`** for a complete list of them.

You can emulate up to four serial ports. Use `-serial none` to disable all serial ports.

`-parallel DEVICE`

Redirects the VM Guest's parallel port to a *DEVICE*. This option supports the same devices as `-serial`.

Tip

With openSUSE Leap as a VM Host Server, you can directly use the hardware parallel port devices `/dev/parportN` where `N` is the number of the port.

You can emulate up to three parallel ports. Use `-parallel none` to disable all parallel ports.

`-monitor CHAR_DEV`

Redirects the QEMU monitor to a character device *CHAR_DEV* on VM Host Server. This option supports the same devices as `-serial`. By default, it is a virtual console (`vc`) in a graphical mode, and `stdio` in non-graphical mode.

For a complete list of available character devices back-ends, see the man page (**`man 1 qemu`**).

34.4 Networking in QEMU

Use the `-netdev` option in combination with `-device` to define a specific type of networking and a network interface card for your VM Guest. The syntax for the `-netdev` option is

```
-netdev type[,prop[=value][,...]]
```

Currently, SUSE supports the following network types: `user`, `bridge`, and `tap`. For a complete list of `-netdev` sub-options, see the manual page (**`man 1 qemu`**).

SUPPORTED `-netdev` SUB-OPTIONS

`bridge`

Uses a specified network helper to configure the TAP interface and attach it to a specified bridge. For more information, see *Section 34.4.3, “Bridged networking”*.

`user`

Specifies user-mode networking. For more information, see *Section 34.4.2, “User-mode networking”*.

`tap`

Specifies bridged or routed networking. For more information, see *Section 34.4.3, “Bridged networking”*.

34.4.1 Defining a network interface card

Use `-netdev` together with the related `-device` option to add a new emulated network card:

```
> sudo qemu-system-x86_64 [...] \
-netdev tap 1 ,id=hostnet0 \
-device virtio-net-pci 2 ,netdev=hostnet0,vlan=1 3 ,\
macaddr=00:16:35:AF:94:4B 4 ,name=ncard1
```

1 Specifies the network device type.

2 Specifies the model of the network card. Use **`qemu-system-ARCH -device help`** and search for the `Network devices:` section to get the list of all network card models supported by QEMU on your platform.
Currently, SUSE supports the models `rtl8139`, `e1000` and its variants `e1000-82540em`, `e1000-82544gc` and `e1000-82545em`, and `virtio-net-pci`. To view a list of options for a specific driver, add `help` as a driver option:

```
> sudo qemu-system-x86_64 -device e1000,help
e1000.mac=macaddr
e1000.vlan=vlan
e1000.netdev=netdev
e1000.bootindex=int32
e1000.autonegotiation=on/off
e1000.mitigation=on/off
e1000.addr=pci-devfn
e1000.romfile=str
e1000.rombar=uint32
e1000.multifunction=on/off
e1000.command_serr_enable=on/off
```

3 Connects the network interface to VLAN number 1. You can specify your own number—it is mainly useful for identification purpose. If you omit this suboption, QEMU uses the default 0.

4 Specifies the Media Access Control (MAC) address for the network card. It is a unique identifier and you are advised to always specify it. If not, QEMU supplies its own default MAC address and creates a possible MAC address conflict within the related VLAN.

34.4.2 User-mode networking

The `-netdev user` option instructs QEMU to use user-mode networking. This is the default if no networking mode is selected. Therefore, these command lines are equivalent:

```
> sudo qemu-system-x86_64 -hda /images/sles_base.raw
```

```
> sudo qemu-system-x86_64 -hda /images/sles_base.raw -netdev user,id=hostnet0
```

This mode is useful to allow the VM Guest to access the external network resources, such as the Internet. By default, no incoming traffic is permitted and therefore, the VM Guest is not visible to other machines on the network. No administrator privileges are required in this networking mode. The user-mode is also useful for doing a network boot on your VM Guest from a local directory on VM Host Server.

The VM Guest allocates an IP address from a virtual DHCP server. VM Host Server (the DHCP server) is reachable at 10.0.2.2, while the IP address range for allocation starts from 10.0.2.15. You can use `ssh` to connect to VM Host Server at 10.0.2.2, and `scp` to copy files back and forth.

34.4.2.1 Command line examples

This section shows several examples on how to set up user-mode networking with QEMU.

EXAMPLE 34.1: RESTRICTED USER-MODE NETWORKING

```
> sudo qemu-system-x86_64 [...] \
-netdev user❶,id=hostnet0 \
-device virtio-net-pci,netdev=hostnet0,vlan=1❷,name=user_net1❸,restrict=yes❹
```

❶ Specifies user-mode networking.

❷ Connects to VLAN number 1. If omitted, defaults to 0.

❸ Specifies a human-readable name of the network stack. Useful when identifying it in the QEMU monitor.

❹ Isolates VM Guest. It then cannot communicate with VM Host Server and no network packets are routed to the external network.

EXAMPLE 34.2: USER-MODE NETWORKING WITH CUSTOM IP RANGE

```
> sudo qemu-system-x86_64 [...] \
-netdev user,id=hostnet0 \
-device virtio-net-pci,netdev=hostnet0,net=10.2.0.0/8❶,host=10.2.0.6❷,\
dhcpstart=10.2.0.20❸,hostname=tux_kvm_guest❹
```

❶ Specifies the IP address of the network that VM Guest sees and optionally the netmask. Default is 10.0.2.0/8.

❷ Specifies the VM Host Server IP address that VM Guest sees. Default is 10.0.2.2.

❸ Specifies the first of the 16 IP addresses that the built-in DHCP server can assign to VM Guest. Default is 10.0.2.15.

❹ Specifies the host name that the built-in DHCP server assigns to VM Guest.

EXAMPLE 34.3: USER-MODE NETWORKING WITH NETWORK-BOOT AND TFTP

```
> sudo qemu-system-x86_64 [...] \
-netdev user,id=hostnet0 \
-device virtio-net-pci,netdev=hostnet0,tftp=/images/tftp_dir❶,\
bootfile=/images/boot/pxelinux.0❷
```

❶ Activates a built-in TFTP (a file transfer protocol with the functionality of a basic FTP) server. The files in the specified directory are visible to a VM Guest as the root of a TFTP server.

❷ Broadcasts the specified file as a BOOTP (a network protocol that offers an IP address and a network location of a boot image, often used in diskless workstations) file. When used together with `tftp`, the VM Guest can boot via the network from the local directory on the host.

EXAMPLE 34.4: USER-MODE NETWORKING WITH HOST PORT FORWARDING

```
> sudo qemu-system-x86_64 [...] \
-netdev user,id=hostnet0 \
-device virtio-net-pci,netdev=hostnet0,hostfwd=tcp::2222-:22
```

Forwards incoming TCP connections to the port 2222 on the host to the port 22 (`SSH`) on VM Guest. If `sshd` is running on VM Guest, enter

```
> ssh qemu_host -p 2222
```

where `qemu_host` is the host name or IP address of the host system, to get a `SSH` prompt from VM Guest.

34.4.3 Bridged networking

With the `-netdev tap` option, QEMU creates a network bridge by connecting the host TAP network device to a specified VLAN of VM Guest. Its network interface is then visible to the rest of the network. This method does not work by default and needs to be explicitly specified.

First, create a network bridge and add a VM Host Server physical network interface to it, such as `eth0`:

1. Start *YaST Control Center* and select *System* › *Network Settings*.
2. Click *Add* and select *Bridge* from the *Device Type* drop-down box in the *Hardware Dialog* window. Click *Next*.
3. Choose whether you need a dynamically or statically assigned IP address, and fill the related network settings if applicable.
4. In the *Bridged Devices* pane, select the Ethernet device to add to the bridge.
   Click *Next*. When asked about adapting an already configured device, click *Continue*.
5. Click *OK* to apply the changes. Check if the bridge is created:

   ```
   > bridge link
   2: eth0 state UP : <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 master br0 \
    state forwarding priority 32 cost 100
   ```

34.4.3.1 Connecting to a bridge manually

Use the following example script to connect VM Guest to the newly created bridge interface `br0`. Several commands in the script are run via the **`sudo`** mechanism because they require `root` privileges.

Tip: Required software

To manage a network bridge, you need to have the `tunctl` package installed.

```
#!/bin/bash
bridge=br0❶
tap=$(sudo tunctl -u $(whoami) -b)❷
sudo ip link set $tap up❸
sleep 1s❹
sudo ip link add name $bridge type bridge
sudo ip link set $bridge up
sudo ip link set $tap master $bridge❺
qemu-system-x86_64 -machine accel=kvm -m 512 -hda /images/sles_base.raw \
 -netdev tap,id=hostnet0 \
 -device virtio-net-pci,netdev=hostnet0,vlan=0,macaddr=00:16:35:AF:94:4B,\
```

```
 ifname=$tap❻,script=no❼,downscript=no
sudo ip link set $tap nomaster❽
sudo ip link set $tap down❾
sudo tunctl -d $tap❿
```

❶ Name of the bridge device.

❷ Prepare a new TAP device and assign it to the user who runs the script. TAP devices are virtual network devices often used for virtualization and emulation setups.

❸ Bring up the newly created TAP network interface.

❹ Make a 1-second pause to make sure the new TAP network interface is really up.

❺ Add the new `TAP` device to the network bridge `br0`.

❻ The `ifname=` suboption specifies the name of the TAP network interface used for bridging.

❼ Before **`qemu-system-ARCH`** connects to a network bridge, it checks the `script` and `downscript` values. If it finds the specified scripts on the VM Host Server file system, it runs the `script` before it connects to the network bridge and `downscript` after it exits the network environment. You can use these scripts to set up and tear down the bridged interfaces. By default, `/etc/qemu-ifup` and `/etc/qemu-ifdown` are examined. If `script=no` and `downscript=no` are specified, the script execution is disabled and you need to take care of it manually.

❽ Deletes the TAP interface from a network bridge `br0`.

❾ Sets the state of the TAP device to `down`.

❿ Tear down the TAP device.

34.4.3.2 Connecting to a bridge with qemu-bridge-helper

Another way to connect VM Guest to a network through a network bridge is via the `qemu-bridge-helper` helper program. It configures the TAP interface for you, and attaches it to the specified bridge. The default helper executable is `/usr/lib/qemu-bridge-helper`. The helper executable is setuid root, which is only executable by the members of the virtualization group (`kvm`). Therefore the **`qemu-system-ARCH`** command itself does not need to be run under `root` privileges.

The helper is automatically called when you specify a network bridge:

```
qemu-system-x86_64 [...] \
 -netdev bridge,id=hostnet0,vlan=0,br=br0 \
 -device virtio-net-pci,netdev=hostnet0
```

You can specify your own custom helper script that takes care of the TAP device (de)configuration, with the `helper=/path/to/your/helper` option:

```
qemu-system-x86_64 [...] \
 -netdev bridge,id=hostnet0,vlan=0,br=br0,helper=/path/to/bridge-helper \
 -device virtio-net-pci,netdev=hostnet0
```

Tip

To define access privileges to `qemu-bridge-helper`, inspect the `/etc/qemu/bridge.conf` file. For example the following directive

```
allow br0
```

allows the **`qemu-system-ARCH`** command to connect its VM Guest to the network bridge `br0`.

34.5 Viewing a VM Guest with VNC

By default QEMU uses a GTK (a cross-platform toolkit library) window to display the graphical output of a VM Guest. With the `-vnc` option specified, you can make QEMU listen on a specified VNC display and redirect its graphical output to the VNC session.

Tip

When working with QEMU's virtual machine via VNC session, it is useful to work with the `-usbdevice tablet` option.

Moreover, if you need to use another keyboard layout than the default `en-us`, specify it with the `-k` option.

The first suboption of `-vnc` must be a *display* value. The `-vnc` option understands the following display specifications:

`host:display`

Only connections from `host` on the display number `display` are accepted. The TCP port on which the VNC session is then running is normally a 5900 + `display` number. If you do not specify `host`, connections are accepted from any host.

`unix:path`

The VNC server listens for connections on Unix domain sockets. The `path` option specifies the location of the related Unix socket.

`none`

The VNC server functionality is initialized, but the server itself is not started. You can start the VNC server later with the QEMU monitor. For more information, see *Chapter 35, Virtual machine administration using QEMU monitor*.

Following the display value there may be one or more option flags separated by commas. Valid options are:

`reverse`

Connect to a listening VNC client via a *reverse* connection.

`websocket`

Opens an additional TCP listening port dedicated to VNC Websocket connections. By definition the Websocket port is 5700 + display.

`password`

Require that password-based authentication is used for client connections.

`tls`

Require that clients use TLS when communicating with the VNC server.

`x509=/path/to/certificate/dir`

Valid if TLS is specified. Require that x509 credentials are used for negotiating the TLS session.

`x509verify=/path/to/certificate/dir`

Valid if TLS is specified. Require that x509 credentials are used for negotiating the TLS session.

`sasl`

Require that the client uses SASL to authenticate with the VNC server.

`acl`

Turn on access control lists for checking of the x509 client certificate and SASL party.

`lossy`

Enable lossy compression methods (gradient, JPEG, ...).

`non-adaptive`

Disable adaptive encodings. Adaptive encodings are enabled by default.

`share=[allow-exclusive|force-shared|ignore]`

Set display sharing policy.

Note

For more details about the display options, see the *qemu-doc* man page.

An example VNC usage:

```
tux > sudo qemu-system-x86_64 [...] -vnc :5
# (on the client:)
wilber > vncviewer venus:5 &
```

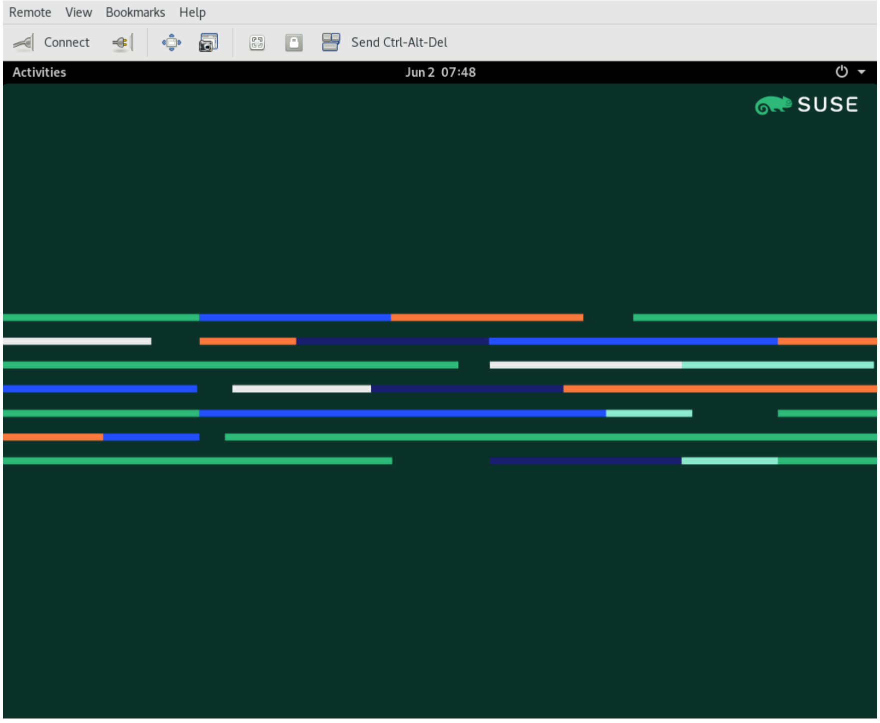


FIGURE 34.2: QEMU VNC SESSION

34.5.1 Secure VNC connections

The default VNC server setup does not use any form of authentication. In the previous example, any user can connect and view the QEMU VNC session from any host on the network.

There are several levels of security that you can apply to your VNC client/server connection. You can either protect your connection with a password, use x509 certificates, use SASL authentication, or even combine several authentication methods in one QEMU command.

For more information about configuring x509 certificates on a VM Host Server and the client, see *Section 11.3.2, "Remote TLS/SSL connection with x509 certificate (`qemu+tls` or `xen+tls`)"* and *Section 11.3.2.3, "Configuring the client and testing the setup"*.

The Remmina VNC viewer supports advanced authentication mechanisms. For this example, let us assume that the server x509 certificates `ca-cert.pem`, `server-cert.pem`, and `server-key.pem` are located in the `/etc/pki/qemu` directory on the host. The client certificates can be placed in any custom directory, as Remmina asks for their path on the connection start-up.

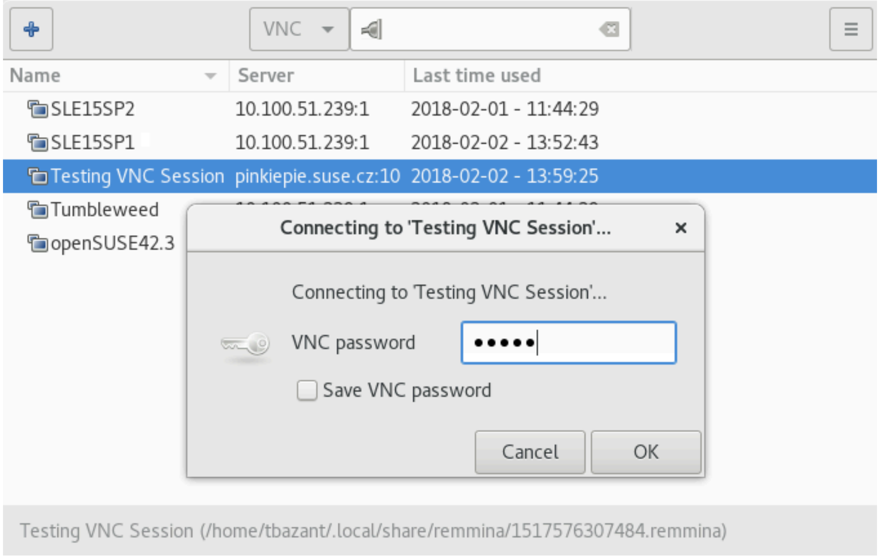
EXAMPLE 34.5: PASSWORD AUTHENTICATION

```
qemu-system-x86_64 [...] -vnc :5,password -monitor stdio
```

Starts the VM Guest graphical output on VNC display number 5 which corresponds to port 5905. The `password` suboption initializes a simple password-based authentication method. There is no password set by default and you need to set one with the **`change vnc password`** command in QEMU monitor:

```
QEMU 2.3.1 monitor - type 'help' for more information
(qemu) change vnc password
Password: ****
```

You need the `-monitor stdio` option here, because you would not be able to manage the QEMU monitor without redirecting its input/output.



Name	Server	Last time used
SLE15SP2	10.100.51.239:1	2018-02-01 - 11:44:29
SLE15SP1	10.100.51.239:1	2018-02-02 - 13:52:43
Testing VNC Session	pinkiepie.suse.cz:10	2018-02-02 - 13:59:25
Tumbleweed		
openSUSE42.3		

Connecting to 'Testing VNC Session'...

Connecting to 'Testing VNC Session'...

VNC password •••••

□ Save VNC password

Testing VNC Session (/home/tbazant/.local/share/remmina/1517576307484.remmina)

FIGURE 34.3: AUTHENTICATION DIALOG IN REMMINA

EXAMPLE 34.6: X509 CERTIFICATE AUTHENTICATION

> The QEMU VNC server can use TLS encryption for the session and x509 certificates for authentication. The server asks the client for a certificate and validates it against the CA certificate. Use this authentication type if your company provides an internal certificate authority.
>
> ```
> qemu-system-x86_64 [...] -vnc :5,tls,x509verify=/etc/pki/qemu
> ```

EXAMPLE 34.7: X509 CERTIFICATE AND PASSWORD AUTHENTICATION

> You can combine the password authentication with TLS encryption and x509 certificate authentication to create a two-layer authentication model for clients. Remember to set the password in the QEMU monitor after you run the following command:
>
> ```
> qemu-system-x86_64 [...] -vnc :5,password,tls,x509verify=/etc/pki/qemu \
> -monitor stdio
> ```

EXAMPLE 34.8: SASL AUTHENTICATION

> Simple Authentication and Security Layer (SASL) is a framework for authentication and data security in Internet protocols. It integrates several authentication mechanisms, like PAM, Kerberos, LDAP and more. SASL keeps its own user database, so the connecting user accounts do not need to exist on VM Host Server.
>
> For security reasons, you are advised to combine SASL authentication with TLS encryption and x509 certificates:
>
> ```
> qemu-system-x86_64 [...] -vnc :5,tls,x509,sasl -monitor stdio
> ```

35 Virtual machine administration using QEMU monitor

When a virtual machine is invoked by the **qemu-system-***ARCH* command, for example **qemu-system-x86_64**, a monitor console is provided for performing interaction with the user. Using the commands available in the monitor console, it is possible to inspect the running operating system, change removable media, take screenshots or audio grabs and control other aspects of the virtual machine.

Note

The following sections list selected useful QEMU monitor commands and their purpose. To get the full list, enter **help** in the QEMU monitor command line.

35.1 Accessing monitor console

Tip: No monitor console for `libvirt`

You can access the monitor console only if you started the virtual machine directly with the **qemu-system-***ARCH* command and are viewing its graphical output in a native QEMU window.

If you started the virtual machine with `libvirt` (for example, using **virt-manager**) and are viewing its output via VNC or Spice sessions, you cannot access the monitor console directly. You can, however, send the monitor command to the virtual machine via **virsh**:

```
# virsh qemu-monitor-command COMMAND
```

The way you access the monitor console depends on which display device you use to view the output of a virtual machine. Find more details about displays in *Section 34.3.2.2, “Display options”*. For example, to view the monitor while the `-display gtk` option is in use, press **Ctrl**–**Alt**–**2**. Similarly, when the `-nographic` option is in use, you can switch to the monitor console by pressing the following key combination: **Ctrl**–**A** **C**.

To get help while using the console, use **help** or **?**. To get help for a specific command, use **help** *COMMAND*.

35.2 Getting information about the guest system

To get information about the guest system, use `info`. If used without any option, the list of possible options is printed. Options determine which part of the system is analyzed:

`info version`

Shows the version of QEMU.

`info commands`

Lists available QMP commands.

`info network`

Shows the network state.

`info chardev`

Shows the character devices.

`info block`

Information about block devices, such as hard disks, floppy drives, or CD-ROMs.

`info blockstats`

Read and write statistics on block devices.

`info registers`

Shows the CPU registers.

`info cpus`

Shows information about available CPUs.

`info history`

Shows the command line history.

`info irq`

Shows the interrupt statistics.

`info pic`

Shows the i8259 (PIC) state.

`info pci`

Shows the PCI information.

`info tlb`

Shows virtual to physical memory mappings.

`info mem`

Shows the active virtual memory mappings.

`info jit`

Shows dynamic compiler information.

`info kvm`

Shows the KVM information.

`info numa`

Shows the NUMA information.

`info usb`

Shows the guest USB devices.

`info usbhost`

Shows the host USB devices.

`info profile`

Shows the profiling information.

`info capture`

Shows the capture (audio grab) information.

`info snapshots`

Shows the currently saved virtual machine snapshots.

`info status`

Shows the current virtual machine status.

`info mice`

Shows which guest mice are receiving events.

`info vnc`

Shows the VNC server status.

`info name`

Shows the current virtual machine name.

`info uuid`

Shows the current virtual machine UUID.

`info usernet`

Shows the user network stack connection states.

`info migrate`

Shows the migration status.

`info balloon`

Shows the balloon device information.

`info qtree`

Shows the device tree.

`info qdm`

Shows the qdev device model list.

`info roms`

Shows the ROMs.

`info migrate_cache_size`

Shows the current migration xbzrle (“Xor Based Zero Run Length Encoding”) cache size.

`info migrate_capabilities`

Shows the status of the multiple migration capabilities, such as xbzrle compression.

`info mtree`

Shows the VM Guest memory hierarchy.

`info trace-events`

Shows available trace-events and their status.

35.3 Changing VNC password

To change the VNC password, use the **`change vnc password`** command and enter the new password:

```
(qemu) change vnc password
Password: ********
(qemu)
```

35.4 Managing devices

To add a new disk while the guest is running (hotplug), use the **drive_add** and **device_add** commands. First define a new drive to be added as a device to bus 0:

```
(qemu) drive_add 0 if=none,file=/tmp/test.img,format=raw,id=disk1
OK
```

You can confirm your new device by querying the block subsystem:

```
(qemu) info block
[...]
disk1: removable=1 locked=0 tray-open=0 file=/tmp/test.img ro=0 drv=raw \
encrypted=0 bps=0 bps_rd=0 bps_wr=0 iops=0 iops_rd=0 iops_wr=0
```

After the new drive is defined, it needs to be connected to a device so that the guest can see it. The typical device would be a `virtio-blk-pci` or `scsi-disk`. To get the full list of available values, run:

```
(qemu) device_add ?
name "VGA", bus PCI
name "usb-storage", bus usb-bus
[...]
name "virtio-blk-pci", bus virtio-bus
```

Now add the device

```
(qemu) device_add virtio-blk-pci,drive=disk1,id=myvirtio1
```

and confirm with

```
(qemu) info pci
[...]
Bus  0, device   4, function 0:
    SCSI controller: PCI device 1af4:1001
      IRQ 0.
      BAR0: I/O at 0xffffffffffffffff [0x003e].
      BAR1: 32 bit memory at 0xffffffffffffffff [0x00000ffe].
      id "myvirtio1"
```

Tip

Devices added with the **device_add** command can be removed from the guest with **device_del**. Enter **help device_del** on the QEMU monitor command line for more information.

To release the device or file connected to the removable media device, use the **eject** *DEVICE* command. Use the optional -f to force ejection.

To change removable media (like CD-ROMs), use the **change** *DEVICE* command. The name of the removable media can be determined using the **info block** command:

```
(qemu) info block
ide1-cd0: type=cdrom removable=1 locked=0 file=/dev/sr0 ro=1 drv=host_device
(qemu) change ide1-cd0 /path/to/image
```

35.5 Controlling keyboard and mouse

It is possible to use the monitor console to emulate keyboard and mouse input if necessary. For example, if your graphical user interface intercepts certain key combinations at low level (such as Ctrl – Alt – F1 in X Window Syustem), you can still enter them using the **sendkey** *KEYS*:

```
sendkey ctrl-alt-f1
```

To list the key names used in the *KEYS* option, enter **sendkey** and press →| .

To control the mouse, the following commands can be used:

mouse_move *DX* *dy* [*DZ*]

Move the active mouse pointer to the specified coordinates dx, dy with the optional scroll axis dz.

mouse_button *VAL*

Change the state of the mouse buttons (1 = left, 2 = middle, 4 = right).

mouse_set *INDEX*

Set which mouse device receives events. Device index numbers can be obtained with the **info mice** command.

35.6 Changing available memory

If the virtual machine was started with the -balloon virtio option (the paravirtualized balloon device is therefore enabled), you can change the available memory dynamically. For more information about enabling the balloon device, see *Section 33.1, “Basic installation with* **qemu-system-ARCH***”*.

To get information about the balloon device in the monitor console and to determine whether the device is enabled, use the `info balloon` command:

```
(qemu) info balloon
```

If the balloon device is enabled, use the `balloon` *`MEMORY_IN_MB`* command to set the requested amount of memory:

```
(qemu) balloon 400
```

35.7 Dumping virtual machine memory

To save the content of the virtual machine memory to a disk or console output, use the following commands:

`memsave` *`ADDR SIZE FILENAME`*

Saves virtual memory dump starting at *`ADDR`* of size *`SIZE`* to file *`FILENAME`*

`pmemsave` *`ADDR SIZE FILENAME`*

Saves physical memory dump starting at *`ADDR`* of size *`SIZE`* to file *`FILENAME`*-

x / *`FMT ADDR`*

Makes a virtual memory dump starting at address *`ADDR`* and formatted according to the *`FMT`* string. The *`FMT`* string consists of three parameters *`COUNTFORMATSIZE`*:
The *`COUNT`* parameter is the number of items to be dumped.
The *`FORMAT`* can be `x` (hex), `d` (signed decimal), `u` (unsigned decimal), `o` (octal), `c` (char) or `i` (assembly instruction).
The *`SIZE`* parameter can be `b` (8 bits), `h` (16 bits), `w` (32 bits) or `g` (64 bits). On x86, `h` or `w` can be specified with the `i` format to respectively select 16 or 32-bit code instruction size.

xp / *`FMT ADDR`*

Makes a physical memory dump starting at address *`ADDR`* and formatted according to the *`FMT`* string. The *`FMT`* string consists of three parameters *`COUNTFORMATSIZE`*:
The *`COUNT`* parameter is the number of the items to be dumped.
The *`FORMAT`* can be `x` (hex), `d` (signed decimal), `u` (unsigned decimal), `o` (octal), `c` (char) or `i` (asm instruction).

The `SIZE` parameter can be `b` (8 bits), `h` (16 bits), `w` (32 bits) or `g` (64 bits). On x86, `h` or `w` can be specified with the `i` format to respectively select 16 or 32-bit code instruction size.

35.8 Managing virtual machine snapshots

Managing snapshots in QEMU monitor is not officially supported by SUSE yet. The information found in this section may be helpful in specific cases.

Virtual Machine snapshots are snapshots of the complete virtual machine including the state of CPU, RAM and the content of all writable disks. To use virtual machine snapshots, you must have at least one non-removable and writable block device using the `qcow2` disk image format.

Snapshots are helpful when you need to save your virtual machine in a particular state. For example, after you have configured network services on a virtualized server and want to quickly start the virtual machine in the same state that was saved last. You can also create a snapshot after the virtual machine has been powered off to create a backup state before you try something experimental and make VM Guest unstable. This section introduces the former case, while the latter is described in *Section 33.2.3, “Managing snapshots of virtual machines with qemu-img”*.

The following commands are available for managing snapshots in QEMU monitor:

`savevm` *`NAME`*

Creates a new virtual machine snapshot under the tag `NAME` or replaces an existing snapshot.

`loadvm` *`NAME`*

Loads a virtual machine snapshot tagged `NAME`.

`delvm`

Deletes a virtual machine snapshot.

`info snapshots`

Prints information about available snapshots.

```
(qemu) info snapshots
Snapshot list:
ID❶       TAG❷                    VM SIZE❸   DATE❹              VM CLOCK❺
1         booting                  4.4M 2013-11-22 10:51:10   00:00:20.476
2         booted                   184M 2013-11-22 10:53:03   00:02:05.394
3         logged_in                273M 2013-11-22 11:00:25   00:04:34.843
```

```
4         ff_and_term_running    372M 2013-11-22 11:12:27   00:08:44.965
```

1. Unique auto-incremented identification number of the snapshot.
2. Unique description string of the snapshot. It is meant as a human readable version of the ID.
3. The disk space occupied by the snapshot. Note that the more memory is consumed by running applications, the bigger the snapshot is.
4. Time and date the snapshot was created.
5. The current state of the virtual machine's clock.

35.9 Suspending and resuming virtual machine execution

The following commands are available for suspending and resuming virtual machines:

`stop`

Suspends the execution of the virtual machine.

`cont`

Resumes the execution of the virtual machine.

`system_reset`

Resets the virtual machine. The effect is similar to the reset button on a physical machine. This may leave the file system in an unclean state.

`system_powerdown`

Sends an *ACPI* shutdown request to the machine. The effect is similar to the power button on a physical machine.

`q` or `quit`

Terminates QEMU immediately.

35.10 Live migration

The live migration process allows to transmit any virtual machine from one host system to another host system without any interruption in availability. It is possible to change hosts permanently or only during maintenance.

The requirements for live migration:

- All requirements from *Section 10.7.1, “Migration requirements”* are applicable.
- Live migration is only possible between VM Host Servers with the same CPU features.
- *AHCI* interface, *VirtFS* feature, and the `-mem-path` command line option are not compatible with migration.
- The guest on the source and destination hosts must be started in the same way.
- `-snapshot` qemu command line option should not be used for migration (and this **`qemu`** command line option is not supported).

Important: Support status

The `postcopy` mode is not yet supported in openSUSE Leap. It is released as a technology preview only. For more information about `postcopy`, see http://wiki.qemu.org/Features/PostCopyLiveMigration ↗.

More recommendations can be found at the following Web site: http://www.linux-kvm.org/page/Migration ↗

The live migration process has the following steps:

1. The virtual machine instance is running on the source host.
2. The virtual machine is started on the destination host in the frozen listening mode. The parameters used are the same as on the source host plus the `-incoming tcp:`*`IP`*`:`*`PORT`* parameter, where *`IP`* specifies the IP address and *`PORT`* specifies the port for listening to the incoming migration. If 0 is set as IP address, the virtual machine listens on all interfaces.
3. On the source host, switch to the monitor console and use the **`migrate -d tcp:`** *`DESTINATION_IP`*`:`*`PORT`* command to initiate the migration.
4. To determine the state of the migration, use the **`info migrate`** command in the monitor console on the source host.
5. To cancel the migration, use the **`migrate_cancel`** command in the monitor console on the source host.

6. To set the maximum tolerable downtime for migration in seconds, use the `migrate_set_downtime` `NUMBER_OF_SECONDS` command.

7. To set the maximum speed for migration in bytes per second, use the `migrate_set_speed` `BYTES_PER_SECOND` command.

35.11 QMP - QEMU machine protocol

QMP is a JSON-based protocol that allows applications—such as `libvirt`—to communicate with a running QEMU instance. There are several ways you can access the QEMU monitor using QMP commands.

35.11.1 Access QMP via standard input/output

The most flexible way to use QMP is by specifying the `-mon` option. The following example creates a QMP instance using standard input/output. In the following examples, `->` marks lines with commands sent from client to the running QEMU instance, while `<-` marks lines with the output returned from QEMU.

```
> sudo qemu-system-x86_64 [...] \
-chardev stdio,id=mon0 \
-mon chardev=mon0,mode=control,pretty=on

<- {
    "QMP": {
        "version": {
            "qemu": {
                "micro": 0,
                "minor": 0,
                "major": 2
            },
            "package": ""
        },
        "capabilities": [
        ]
    }
}
```

When a new QMP connection is established, QMP sends its greeting message and enters capabilities negotiation mode. In this mode, only the `qmp_capabilities` command works. To exit capabilities negotiation mode and enter command mode, the `qmp_capabilities` command must be issued first:

```
-> { "execute": "qmp_capabilities" }
<- {
    "return": {
    }
}
```

Note that `"return": {}` is a QMP's success response.

QMP's commands can have arguments. For example to eject a CD-ROM drive, enter the following:

```
->{ "execute": "eject", "arguments": { "device": "ide1-cd0" } }
<- {
    "timestamp": {
        "seconds": 1410353381,
        "microseconds": 763480
    },
    "event": "DEVICE_TRAY_MOVED",
    "data": {
        "device": "ide1-cd0",
        "tray-open": true
    }
}
{
    "return": {
    }
}
```

35.11.2 Access QMP via telnet

Instead of the standard input/output, you can connect the QMP interface to a network socket and communicate with it via a specified port:

```
> sudo qemu-system-x86_64 [...] \
-chardev socket,id=mon0,host=localhost,port=4444,server,nowait \
-mon chardev=mon0,mode=control,pretty=on
```

And then run telnet to connect to port 4444:

```
> telnet localhost 4444
```

```
Trying ::1...
Connected to localhost.
Escape character is '^]'.
<- {
    "QMP": {
        "version": {
            "qemu": {
                "micro": 0,
                "minor": 0,
                "major": 2
            },
            "package": ""
        },
        "capabilities": [
        ]
    }
}
```

You can create several monitor interfaces at the same time. The following example creates one HMP instance—human monitor which understands 'normal' QEMU monitor's commands—on the standard input/output, and one QMP instance on localhost port 4444:

```
> sudo qemu-system-x86_64 [...] \
-chardev stdio,id=mon0 -mon chardev=mon0,mode=readline \
-chardev socket,id=mon1,host=localhost,port=4444,server,nowait \
  -mon chardev=mon1,mode=control,pretty=on
```

35.11.3 Access QMP via Unix socket

Invoke QEMU using the `-qmp` option, and create a Unix socket:

```
> sudo qemu-system-x86_64 [...] \
-qmp unix:/tmp/qmp-sock,server --monitor stdio

QEMU waiting for connection on: unix:./qmp-sock,server
```

To communicate with the QEMU instance via the `/tmp/qmp-sock` socket, use **`nc`** (see **`man 1 nc`** for more information) from another terminal on the same host:

```
> sudo nc -U /tmp/qmp-sock
<- {"QMP": {"version": {"qemu": {"micro": 0, "minor": 0, "major": 2} [...]
```

35.11.4 Access QMP via `libvirt`'s **`virsh`** command

If you run your virtual machines under `libvirt` (see *Part II, “Managing virtual machines with `libvirt`”*), you can communicate with its running guests by running the **`virsh qemu-monitor-command`**:

```
> sudo virsh qemu-monitor-command vm_guest1 \
--pretty '{"execute":"query-kvm"}'
<- {
    "return": {
        "enabled": true,
        "present": true
    },
    "id": "libvirt-8"
}
```

In the above example, we ran the simple command **`query-kvm`** which checks if the host is capable of running KVM and if KVM is enabled.

Tip: Generating human-readable output

To use the standard human-readable output format of QEMU instead of the JSON format, use the `--hmp` option:

```
> sudo virsh qemu-monitor-command vm_guest1 --hmp "query-kvm"
```

VI Troubleshooting

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36 Integrated help and package documentation

Virtualization packages provide commands for managing many aspects of a virtualization host. It is not possible or expected to remember all options supported by these commands. A basic installation of a Xen or KVM host includes manual pages and integrated help for shell commands. The documentation sub-packages provide additional content beyond what is provided by the basic installation.

Manual pages for shell commands

Most commands include a manual page that provides detailed information about the command, describes any options, and in certain cases gives example command usage. For example, to see the manual for the **`virt-install`** command type:

```
> man virt-install
```

Integrated help for shell commands

Commands also include integrated help, providing more compact and topic-driven documentation. For example, to see a brief description of the **`virt-install`** command type:

```
> virt-install --help
```

Integrated help can also be used to see the details of a specific option. For example, to see the sub-options supported by the disk option type:

```
> virt-install --disk help
```

Documentation sub-packages

Many of the virtualization packages provide additional content in their documentation sub-package. As an example, the `libvirt-doc` package contains all the documentation available at http://libvirt.org↗, plus sample code demonstrating the use of the libvirt C API. Use the **`rpm`** command to view the contents of a documentation sub-package. For example, to see the contents of `libvirt-doc`:

```
rpm -ql libvirt-doc
```

37 Gathering system information and logs

In certain cases logs generated from a custom logging or debugging configuration may be required to determine the cause of a problem.

37.1 `libvirt` log controls

`libvirt` provides logging facilities for both the library and the daemon. The behavior of the logging facility is controlled by adjusting the log level, filter and output settings.

Log level

`libvirt` log messages are classified into four priority levels: DEBUG, INFO, WARNING and ERROR. The DEBUG level is verbose and capable of generating gigabytes of information in a short time. The volume of log messages progressively decreases with the INFO, WARNING and ERROR log levels. ERROR is the default log level.

Log filters

Log filters provide a way to log only messages matching a specific component and log level. Log filters allow collecting the verbose DEBUG log messages of specific components, but only ERROR level log messages from the rest of the system. By default, no log filters are defined.

Log outputs

Log outputs allow specifying where the filtered log messages are sent. Messages can be sent to a file, the standard error stream of the process, or journald. By default, filtered log messages are sent to journald.

See https://libvirt.org/logging.html for more details on `libvirt`'s log controls.

A default `libvirt` installation has the log level set to ERROR, no log filters defined, and log outputs set to journald. Log messages from the `libvirt` daemon can be viewed with the **`journalctl`** command:

```
# journalctl --unit libvirtd
```

The default log facility settings are fine for normal operations and provide useful messages for applications and users of `libvirt`, but internal issues often require DEBUG level messages. As an example, consider a potential bug in the interaction between `libvirt` and the QEMU monitor. In this case, we only need to see the debug messages of the communication between `libvirt` and QEMU. The following example creates a log filter to select debug messages from the QEMU driver and send them to a file named `/tmp/libvirtd.log`

```
    log_filters="1:qemu.qemu_monitor_json"
    log_outputs="1:file:/tmp/libvirtd.log"
```

Log controls for the `libvirt` daemon can be found in `/etc/libvirt/libvirtd.conf`. The daemon must be restarted after making any changes to the configuration file.

```
# systemctl restart libvirtd.service
```

Glossary

General

Create Virtual Machine Wizard

A software program available in YaST and Virtual Machine Manager that provides a graphical interface to guide you through the steps to create virtual machines. It can also be run in text mode by entering `virt-install` at a command prompt in the host environment.

Dom0

The term is used in Xen environments, and refers to a virtual machine. The host operating system is a virtual machine running in a privileged domain and can be called Dom0. All other virtual machines on the host run in unprivileged domains and can be called domain U's.

hardware-assisted

Intel* and AMD* provide virtualization hardware-assisted technology. This reduces the frequency of VM IN/OUT (fewer VM traps), because software is a major source of overhead, and increases the efficiency (the execution is done by the hardware). Moreover, this reduces the memory footprint, provides better resource control, and allows secure assignment of specific I/O devices.

Host Environment

The desktop or command line environment that allows interaction with the host computer's environment. It provides a command line environment and can also include a graphical desktop, such as GNOME or IceWM. The host environment runs as a special type of virtual machine that has privileges to control and manage other virtual machines. Other commonly used terms include *Dom0*, privileged domain, and host operating system.

Hypervisor

The software that coordinates the low-level interaction between virtual machines and the underlying physical computer hardware.

KVM

See *Chapter 4, Introduction to KVM virtualization*

Paravirtualized Frame Buffer

The video output device that drives a video display from a memory buffer containing a complete frame of data for virtual machine displays running in paravirtual mode.

VHS

Virtualization Host Server

The physical computer running a SUSE virtualization platform software. The virtualization environment consists of the hypervisor, the host environment, virtual machines and associated tools, commands and configuration files. Other commonly used terms include host, Host Computer, Host Machine (HM), Virtual Server (VS), Virtual Machine Host (VMH), and VM Host Server (VHS).

VirtFS

VirtFS is a new paravirtualized file system interface designed for improving pass-through technologies in the KVM environment. It is based on the VirtIO framework.

Virtualized

A guest operating system or application running on a virtual machine.

Virtual Machine

A virtualized PC environment (VM) capable of hosting a guest operating system and associated applications. Could be also called a VM Guest.

Virtual Machine Manager

A software program that provides a graphical user interface for creating and managing virtual machines.

Xen

See *Chapter 3, Introduction to Xen virtualization*

xl

A set of commands for Xen that lets administrators manage virtual machines from a command prompt on the host computer. It replaced the deprecated `xm` tool stack.

CPU

CPU capping

Virtual CPU capping allows you to set vCPU capacity to 1–100 percent of the physical CPU capacity.

CPU hotplugging

CPU hotplugging is used to describe the functions of replacing/adding/removing a CPU without shutting down the system.

CPU over-commitment

Virtual CPU over-commitment is the ability to assign more virtual CPUs to VMs than the actual number of physical CPUs present in the physical system. This procedure does not increase the overall performance of the system, but may be useful for testing purposes.

CPU pinning

Processor affinity, or CPU pinning enables the binding and unbinding of a process or a thread to a central processing unit (CPU) or a range of CPUs.

Network

Bridged Networking

A type of network connection that lets a virtual machine be identified on an external network as a unique identity that is separate from and unrelated to its host computer.

Empty Bridge

A type of network bridge that has no physical network device or virtual network device provided by the host. This lets virtual machines communicate with other virtual machines on the same host but not with the host or on an external network.

External Network

The network outside a host's internal network environment.

Internal Network

A type of network configuration that restricts virtual machines to their host environment.

Local Bridge

A type of network bridge that has a virtual network device but no physical network device provided by the host. This lets virtual machines communicate with the host and other virtual machines on the host. Virtual machines can communicate on an external network through the host.

Network Address Translation (NAT)

A type of network connection that lets a virtual machine use the IP address and MAC address of the host.

No Host Bridge

A type of network bridge that has a physical network device but no virtual network device provided by the host. This lets virtual machines communicate on an external network but not with the host. This lets you separate virtual machine network communications from the host environment.

Traditional Bridge

A type of network bridge that has both a physical network device and a virtual network device provided by the host.

Storage

AHCI

The Advanced Host Controller Interface (AHCI) is a technical standard defined by Intel* that specifies the operation of Serial ATA (SATA) host bus adapters in a non-implementation-specific manner.

Block Device

Data storage devices, such as CD-ROM drives or disk drives, that move data in the form of blocks. Partitions and volumes are also considered block devices.

File-Backed Virtual Disk

A virtual disk based on a file, also called a disk image file.

Raw Disk

A method of accessing data on a disk at the individual byte level instead of through its file system.

Sparse image file

A disk image file that does not reserve its entire amount of disk space but expands as data is written to it.

xvda

The drive designation given to the first virtual disk on a paravirtual machine.

Acronyms

ACPI

Advanced Configuration and Power Interface (ACPI) specification provides an open standard for device configuration and power management by the operating system.

AER

Advanced Error Reporting

AER is a capability provided by the PCI Express specification which allows for reporting of PCI errors and recovery from some of them.

APIC

Advanced Programmable Interrupt Controller (APIC) is a family of interrupt controllers.

BDF

Bus:Device:Function

Notation used to succinctly describe PCI and PCIe devices.

CG

Control Groups

Feature to limit, account and isolate resource usage (CPU, memory, disk I/O, etc.).

EDF

Earliest Deadline First

This scheduler provides weighted CPU sharing in an intuitive way and uses real-time algorithms to ensure time guarantees.

EPT

Extended Page Tables

Performance in a virtualized environment is close to that in a native environment. Virtualization does create some overheads, however. These come from the virtualization of the CPU, the *MMU*, and the I/O devices. In some recent x86 processors AMD and Intel have begun to provide hardware extensions to help bridge this performance gap. In 2006, both vendors introduced their first generation hardware support for x86 virtualization with AMD-Virtualization (AMD-V) and Intel® VT-x technologies. Recently Intel introduced its second generation of hardware support that incorporates MMU-virtualization, called Extended Page Tables (EPT). EPT-enabled systems can improve performance compared to using shadow paging for *MMU* virtualization. EPT increases memory access latencies for a few workloads. This cost can be reduced by effectively using large pages in the guest and the hypervisor.

FLASK

Flux Advanced Security Kernel

Xen implements a type of mandatory access control via a security architecture called FLASK using a module of the same name.

HAP

High Assurance Platform

HAP combines hardware and software technologies to improve workstation and network security.

HVM

Hardware Virtual Machine (commonly called like this by Xen).

IOMMU

Input/Output Memory Management Unit

IOMMU (AMD* technology) is a memory management unit (*MMU*) that connects a direct memory access-capable (DMA-capable) I/O bus to the main memory.

KSM

Kernel Same Page Merging

KSM allows for automatic sharing of identical memory pages between guests to save host memory. KVM is optimized to use KSM if enabled on the VM Host Server.

MMU

Memory Management Unit

is a computer hardware component responsible for handling accesses to memory requested by the CPU. Its functions include translation of virtual addresses to physical addresses (that is, virtual memory management), memory protection, cache control, bus arbitration and in simpler computer architectures (especially 8-bit systems) bank switching.

PAE

Physical Address Extension

32-bit x86 operating systems use Physical Address Extension (PAE) mode to enable addressing of more than 4 GB of physical memory. In PAE mode, page table entries (PTEs) are 64 bits in size.

PCID

Process-context identifiers

These are a facility by which a logical processor may cache information for multiple linear-address spaces so that the processor may retain cached information when software switches to a different linear address space. INVPCID instruction is used for fine-grained *TLB* flush, which is benefit for kernel.

PCIe

Peripheral Component Interconnect Express

PCIe was designed to replace older PCI, PCI-X and AGP bus standards. PCIe has numerous improvements including a higher maximum system bus throughput, a lower I/O pin count and smaller physical footprint. Moreover it also has a more detailed error detection and reporting mechanism (*AER*), and a native hotplug functionality. It is also backward compatible with PCI.

PSE and PSE36

Page Size Extended

PSE refers to a feature of x86 processors that allows for pages larger than the traditional 4 KiB size. PSE-36 capability offers 4 more bits, in addition to the normal 10 bits, which are used inside a page directory entry pointing to a large page. This allows a large page to be located in 36-bit address space.

PT

Page Table

A page table is the data structure used by a virtual memory system in a computer operating system to store the mapping between virtual addresses and physical addresses. Virtual addresses are those unique to the accessing process. Physical addresses are those unique to the hardware (RAM).

QXL

QXL is a cirrus VGA framebuffer (8M) driver for virtualized environment.

RVI or NPT

Rapid Virtualization Indexing, Nested Page Tables

An AMD second generation hardware-assisted virtualization technology for the processor memory management unit (*MMU*).

SATA

Serial ATA

SATA is a computer bus interface that connects host bus adapters to mass storage devices such as hard disks and optical drives.

Seccomp2-based sandboxing

Sandboxed environment where only predetermined system calls are permitted for added protection against malicious behavior.

SMEP

Supervisor Mode Execution Protection

This prevents the execution of user-mode pages by the Xen hypervisor, making many application-to-hypervisor exploits much harder.

SPICE

Simple Protocol for Independent Computing Environments

SXP

An SXP file is a Xen Configuration File.

TCG

Tiny Code Generator

Instructions are emulated rather than executed by the CPU.

THP

Transparent Huge Pages

This allows CPUs to address memory using pages larger than the default 4 KB. This helps reduce memory consumption and CPU cache usage. KVM is optimized to use THP (via madvise and opportunistic methods) if enabled on the VM Host Server.

TLB

Translation Lookaside Buffer

TLB is a cache that memory management hardware uses to improve virtual address translation speed. All current desktop, notebook, and server processors use a TLB to map virtual and physical address spaces, and it is nearly always present in any hardware that uses virtual memory.

VCPU

A scheduling entity, containing each state for virtualized CPU.

VDI

Virtual Desktop Infrastructure

VFIO

Since kernel v3.6; a new method of accessing PCI devices from user space called VFIO.

VHS

Virtualization Host Server

VMCS

Virtual Machine Control Structure

VMX non-root operation and VMX transitions are controlled by a data structure called a virtual-machine control structure (VMCS). Access to the VMCS is managed through a component of processor state called the VMCS pointer (one per logical processor). The value of the VMCS pointer is the 64-bit address of the VMCS. The VMCS pointer is read and written using the instructions VMPTRST and VMPTRLD. The *VMM* configures a VMCS using the VMREAD, VMWRITE, and VMCLEAR instructions. A *VMM* could use a different VMCS for each virtual machine that it supports. For a virtual machine with multiple logical processors (virtual processors), the *VMM* could use a different VMCS for each virtual processor.

VMDq

Virtual Machine Device Queue

Multi-queue network adapters exist which support multiple VMs at the hardware level, having separate packet queues associated to the different hosted VMs (by means of the IP addresses of the VMs).

VMM

Virtual Machine Monitor (Hypervisor)

When the processor encounters an instruction or event of interest to the Hypervisor (*VMM*), it exits from guest mode back to the VMM. The VMM emulates the instruction or other event, at a fraction of native speed, and then returns to guest mode. The transitions from guest mode to the VMM and back again are high-latency operations, during which guest execution is completely stalled.

VM root

VMM will run in *VMX* root operation and guest software will run in *VMX* non-root operation. Transitions between *VMX* root operation and *VMX* non-root operation are called *VMX* transitions.

VMX

Virtual Machine eXtensions

VPID

New support for software control of *TLB* (VPID improves *TLB* performance with small *VMM* development effort).

VT-d

Virtualization Technology for Directed I/O

Like *IOMMU* for Intel* (https://software.intel.com/en-us/articles/intel-virtualization-technology-for-directed-io-vt-d-enhancing-intel-platforms-for-efficient-virtualization-of-io-devices) ↗.

vTPM

Component to establish end-to-end integrity for guests via Trusted Computing.

A Configuring GPU Pass-Through for NVIDIA cards

A.1 Introduction

This article describes how to assign an NVIDIA GPU graphics card on the host machine to a virtualized guest.

A.2 Prerequisites

- GPU pass-through is supported on the AMD64/Intel 64 architecture only.
- This article deals with a set of instructions based on V100/T1000 NVIDIA cards, and is meant for GPU computation purposes only.
- Verify that you are using an NVIDIA Tesla product—Maxwell, Pascal, or Volta.
- To manage the host system, you need an additional display card on the host that you can use when configuring the GPU pass-through, or a functional SSH environment.

A.3 Configuring the host

A.3.1 Verify the host environment

1. Verify that the host supports *VT-d* technology and that it is already enabled in the firmware settings:

   ```
   > dmesg | grep -e "Directed I/O"
   [   12.819760] DMAR: Intel(R) Virtualization Technology for Directed I/O
   ```

   If VT-d is not enabled in the firmware, enable it and reboot the host.

2. Verify that the host has an extra GPU or VGA card:

   ```
   > lspci | grep -i "vga"
   07:00.0 VGA compatible controller: Matrox Electronics Systems Ltd. \
   ```

```
  MGA G200e [Pilot] ServerEngines (SEP1) (rev 05)
```

With a Tesla V100 card:

```
> lspci | grep -i nvidia
03:00.0 3D controller: NVIDIA Corporation GV100 [Tesla V100 PCIe] (rev a1)
```

With a T1000 Mobile (available on Dell 5540):

```
> lspci | grep -i nvidia
01:00.0 3D controller: NVIDIA Corporation TU117GLM [Quadro T1000 Mobile] (rev a1)
```

A.3.2 Enable IOMMU

IOMMU is disabled by default. You need to enable it at boot time in the `/etc/default/grub` configuration file.

1. For Intel-based hosts:

   ```
   GRUB_CMDLINE_LINUX="intel_iommu=on iommu=pt rd.driver.pre=vfio-pci"
   ```

   For AMD-based hosts:

   ```
   GRUB_CMDLINE_LINUX="iommu=pt amd_iommu=on rd.driver.pre=vfio-pci"
   ```

2. When you save the modified `/etc/default/grub` file, re-generate the main GRUB 2 configuration file `/boot/grub2/grub.cfg`:

   ```
   > sudo grub2-mkconfig -o /boot/grub2/grub.cfg
   ```

3. Reboot the host and verify that *IOMMU* is enabled:

   ```
   > dmesg |  grep -e DMAR -e IOMMU
   ```

A.3.3 Blacklist the Nouveau driver

To assign the NVIDIA card to a VM guest, we need to prevent the host OS from loading the built-in `nouveau` driver for NVIDIA GPUs. Create the file `/etc/modprobe.d/60-blacklist-nouveau.conf` with the following content:

```
blacklist nouveau
```

A.3.4 Configure VFIO and isolate the GPU used for pass-through

1. Find the card vendor and model IDs. Use the bus number identified in *Section A.3.1, “Verify the host environment”*, for example, `03:00.0`:

   ```
   > lspci -nn | grep 03:00.0
   03:00.0 3D controller [0302]: NVIDIA Corporation GV100 [Tesla V100 PCIe] [10de:1db4]
    (rev a1)
   ```

2. Create the file `/etc/modprobe.d/vfio.conf` with the following content:

   ```
   options vfio-pci ids=10de:1db4
   ```

   ### Note

   Verify that your card does not need an extra `ids=` parameter. For certain cards, you must specify the audio device too, therefore device's ID must also be added to the list, otherwise you cannot use the card.

A.3.5 Load the VFIO driver

There are three ways you can load the *VFIO* driver.

A.3.5.1 Including the driver in the initrd file

1. Create the file `/etc/dracut.conf.d/gpu-passthrough.conf` and add the following content (mind the leading whitespace):

   ```
   add_drivers+=" vfio vfio_iommu_type1 vfio_pci vfio_virqfd"
   ```

2. Re-generate the initrd file:

   ```
   > sudo dracut --force /boot/initrd $(uname -r)
   ```

A.3.5.2 Adding the driver to the list of auto-loaded modules

Create the file `/etc/modules-load.d/vfio-pci.conf` and add the following content:

```
vfio
```

```
vfio_iommu_type1
vfio_pci
kvm
kvm_intel
```

A.3.5.3 Loading the driver manually

To load the driver manually at runtime, execute the following command:

```
> sudo modprobe vfio-pci
```

A.3.6 Disable MSR for Microsoft Windows guests

For Microsoft Windows guests, we recommend disabling MSR (model-specific register) to avoid the guest crashing. Create the file `/etc/modprobe.d/kvm.conf` and add the following content:

```
options kvm ignore_msrs=1
```

A.3.7 Install UEFI firmware

For proper GPU pass-through functionality, the host needs to boot using UEFI firmware (that is, not using a legacy-style BIOS boot sequence). Install the `qemu-ovmf` package if not already installed:

```
> sudo zypper install qemu-ovmf
```

A.3.8 Reboot the host machine

For most of the changes in the above steps to take effect, you need to reboot the host machine:

```
> sudo shutdown -r now
```

A.4 Configuring the guest

This section describes how to configure the guest virtual machine so that it can use the host's NVIDIA GPU. Use Virtual Machine Manager or **`virt-install`** to install the guest VM. Find more details in *Chapter 9, Guest installation*.

A.4.1 Requirements for the guest configuration

During the guest VM installation, select *Customize configuration before install* and configure the following devices:

- Use Q35 chipset if possible.
- Install the guest VM using UEFI firmware.
- Add the following emulated devices:
  Graphic: Spice or VNC
  Device: qxl, VGA or Virtio
  Find more information in *Section 13.6, "Video"*.
- Add the host PCI device (`03:00.0` in our example) to the guest. Find more information in *Section 13.12, "Assigning a host PCI device to a VM Guest"*.
- For the best performance, we recommend using virtio drivers for the network card and storage.

A.4.2 Install the graphic card driver

A.4.2.1 Linux guest

PROCEDURE A.1: RPM-BASED DISTRIBUTIONS

1. Download the driver RPM package from http://www.nvidia.com/download/driverResults.aspx/131159/en-us ↗.
2. Install the downloaded RPM package:

   ```
   > sudo rpm -i nvidia-diag-driver-local-repo-sles123-390.30-1.0-1.x86_64.rpm
   ```

3. Refresh repositories and install `cuda-drivers` . This step is different for non-SUSE distributions:

   ```
   > sudo zypper refresh && zypper install cuda-drivers
   ```

4. Reboot the guest VM:

   ```
   > sudo shutdown -r now
   ```

PROCEDURE A.2: GENERIC INSTALLER

1. Because the installer needs to compile the NVIDIA driver modules, install the `gcc-c++` and `kernel-devel` packages.

2. Disable Secure Boot on the guest, because NVIDIA's driver modules are unsigned. On SUSE distributions, you can use the YaST GRUB 2 module to disable Secure Boot. Find more information in *Book* “Reference”, *Chapter 14 “UEFI (Unified Extensible Firmware Interface)”, Section 14.1.1 “Implementation on openSUSE Leap”*.

3. Download the driver installation script from https://www.nvidia.com/Download/index.aspx?lang=en-us, make it executable and run it to complete the driver installation:

```
> chmod +x NVIDIA-Linux-x86_64-460.73.01.run
> sudo ./NVIDIA-Linux-x86_64-460.73.01.run
```

4. Download CUDA drivers from https://developer.nvidia.com/cuda-downloads?target_os=Linux&target_arch=x86_64&target_distro=SLES&target_version=15&target_type=rpmlocal and install following the on-screen instructions.

Note: Display issues

After you have installed the NVIDIA drivers, the Virtual Machine Manager display loses its connection to the guest OS. To access the guest VM, you must either login via **`ssh`**, change to the console interface, or install a dedicated VNC server in the guest. To avoid a flickering screen, stop and disable the display manager:

```
> sudo systemctl stop display-manager && systemctl disable display-manager
```

PROCEDURE A.3: TESTING THE LINUX DRIVER INSTALLATION

1. Change the directory to the CUDA sample templates:

```
> cd /usr/local/cuda-9.1/samples/0_Simple/simpleTemplates
```

2. Compile and run the `simpleTemplates` file:

```
> make && ./simpleTemplates
runTest<float,32>
GPU Device 0: "Tesla V100-PCIE-16GB" with compute capability 7.0
CUDA device [Tesla V100-PCIE-16GB] has 80 Multi-Processors
Processing time: 495.006000 (ms)
```

```
Compare OK
runTest<int,64>
GPU Device 0: "Tesla V100-PCIE-16GB" with compute capability 7.0
CUDA device [Tesla V100-PCIE-16GB] has 80 Multi-Processors
Processing time: 0.203000 (ms)
Compare OK
[simpleTemplates] -> Test Results: 0 Failures
```

A.4.2.2 Microsoft Windows guest

Important

Before you install the NVIDIA drivers, you need to hide the hypervisor from the drivers by using the `<hidden state='on'/>` directive in the guest's `libvirt` definition, for example:

```
<features>
 <acpi/>
 <apic/>
 <kvm>
  <hidden state='on'/>
 </kvm>
</features>
```

1. Download and install the NVIDIA driver from https://www.nvidia.com/Download/index.aspx.
2. Download and install the CUDA toolkit from https://developer.nvidia.com/cuda-downloads?target_os=Windows&target_arch=x86_64.
3. Find several NVIDIA demo samples in the directory `Program Files\Nvidia GPU Computing Toolkit\CUDA\v10.2\extras\demo_suite` on the guest.

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